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Vol. XVI.

*On Schwartzembergite.*¹

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[Read June 16, 1908, and January 24, 1911.]

THE mineral schwartzembergite was first described by Domeyko² in 1864 as an oxychloriodide of lead from the Desert of Atacama. The specimens, which are said to have been collected about ten leagues³ from Paposo in the Desert of Atacama, at a mine worked for argentiferous galena, were brought to his notice by Dr. Schwartzemberg, an assayer at Copiapo, who had recognized the material as being an iodide of lead. Domeyko made a chemical analysis (see p. 82) of the mineral, a yellowish crust, 1 to 2 mm. in thickness, upon galena, and obtained the formula,⁴ $2\text{Pb}(\text{Cl}, \text{I})_2 \cdot 3\text{PbO}$, the specific gravity being 5.7; no crystal measurements were obtainable, neither were any optical observations made. The investigation could not be continued because most of the specimens were stolen on their way down from the mine, since it was supposed that they must, because of the care bestowed upon them, contain silver iodide, which also is found at the same mine. A little later, an analysis (see p. 82) was made by Liebe,⁵ who had received some specimens

¹ Communicated by permission of the Trustees of the British Museum.

² I. Domeyko, *Annales des Mines*, 1864, ser. 6, vol. v, p. 453.

³ One Spanish league is nearly equal to four English miles.

⁴ This is the modern form; Domeyko wrote the formula as $2\text{Pb}(\text{Cl}_2, \text{I})3\text{PbO}$.

⁵ K. T. Liebe, *Neues Jahrb. Min.*, 1867, pp. 159-164.

from H. Ferber, a mining engineer, to whom they had been given by Schwartzemberg, and he deduced the formula,¹ $\text{PbI}_2 \cdot 2\text{PbO}$. His material, which was a little denser, the specific gravity being 6.2, was not very pure, and contained both the sulphate and the carbonate of lead; it was mostly amorphous, but appeared in parts in the form of small rhombohedral crystals resembling chalybite. In the fifth edition of his 'System of Mineralogy', published in 1868, J. D. Dana assigned to the new mineral the name, schwartzembergite, by which it is now known. Domeyko, in the third edition of his book on mineralogy,² published in 1879, brings together all that is known of the mineral, its localities and paragenesis. Bertrand³ a little later examined under the microscope some fragments of the mineral from San Rafael and found them to yield a negative uniaxial interference-figure, but he gives no other details.

In 1903, several specimens formerly belonging to the collection of Theodor Hohmann (1843-1897), a mining engineer in Chili, were acquired by the Trustees of the British Museum. Among them were three labelled schwartzembergite, San Rafael mine, Sierra Gorda, Caracoles, Chili, which displayed numerous yellow and brownish crystals, some of them being comparatively large. The form of these crystals is obviously tetragonal,⁴ and not rhombohedral as had been previously described.

Morphological and Optical Characters. (G. F. H. S.)

On the first specimen (86453 of the Museum Register) the crystals are large, being as much as 6 mm. across, and are honey-yellow to reddish-brown in colour. They occur in groups associated with gypsum, percyllite, and corroded quartz. On the second specimen (86454) the crystals are much smaller, never exceeding 1 mm. across; the colour does not consequently reach so deep a brown. Besides gypsum and percyllite, the specimen has on it tiny crystals of paralaurionite (rafaelite). On the third specimen (86455) the crystals are also small, and are intimately associated with gypsum, percyllite, and quartz.

The colour of the crystals depends upon their size. When they are quite small, the colour is honey-yellow, but with increasing thickness it

¹ The formula was given in the old form $\text{PbI} \cdot 2\text{PbO}$.

² I. Domeyko, 'Mineralojía,' 3rd edit., Santiago, 1879, pp. 319-321.

³ É. Bertrand, 'Étude optique de différents minéraux,' Bull. Soc. Min. de France, 1881, vol. iv, p. 87.

⁴ In an editorial note it is stated, '... the last-named [schwartzembergite] being in well-developed tetragonal crystals.' Mineralogical Magazine, 1903, vol. xiii, p. 382.

becomes brownish and finally reddish; the powder, on the other hand, is always straw-yellow in colour. The crystals are very flat, and their contour is square with more or less rounded corners. They are formed of eight low pyramids, four above and four below, directly above one another in pairs. The pyramids are so much rounded that the shape of the crystals approximates to a very flat cone. A small secondary pyramidal form (q) is occasionally seen which is very steep and makes equal angles with the contiguous large pyramids; each face has another lying below it. The crystals are usually attached at the side, and complete development is very rare.

If a crystal be mounted upon a two- or three-circle goniometer and revolved, it is at once perceived that ordinary measurements are quite out of the question. A continuous band of light is given by the pyramidal faces on each half of the crystal, and no distinct images of the object-slit from which readings can be taken are visible. The images given by the small pyramidal faces are better defined; the faces are double, the two parts being mutually inclined at a small re-entrant angle. A form of camera lucida¹ was devised for attachment to the goniometer, by means of which the 'light-figures' given when a pin-hole signal was used could be drawn immediately upon a stereographic projection. These figures are of the type shown in fig. 1. The connecting bands lie very nearly in zones intersecting at right angles. At the poles of intersection, p , which represent a considerable area in the centre of each of the large faces, there is an increase of intensity of the light and often some frilling of the figure in the zone [cp] away from the pole c . The distance cp is about $23\frac{1}{2}^\circ$, but values as low as 16° have been observed. The azimuthal angles at the pole c approximate to 90° , but values as low as 71° have been observed. The other form q is planer, and better readings of the distance have been obtained; cq is about $67^\circ 40'$. If p be given the indices (011), q becomes (441), and the calculated value of cp is $23^\circ 17'$: the axial ratio $a : c = 1 : 0.430$. A distinct cleavage parallel to c (001) was noticed.

That the symmetry of schwartzembergite, however, is pseudo-tetragonal in character is shown by a study of the optical properties as revealed in polarized light. Owing to the high refractivity, immersion in oil is necessary for a satisfactory observation. Through each of the faces of the form p a biaxial interference-figure, of negative birefringence,

¹ G. F. H. Smith, 'A camera lucida attachment for the goniometer,' Mineralogical Magazine, 1910, vol. xv, pp. 388-389.

is visible; the plane of the optic axes is parallel to the corresponding horizontal edge of the contour (fig. 2), the centre of the figure being about 36° from the centre of the field of the microscope, and the angle in air between the optic axes about 38° . Between the large faces lie smaller sectors through which also a biaxial interference-figure is visible, with negative birefringence, but much larger axial angle, about 84° in air. The plane of the optic axes is now perpendicular to the horizontal contour, and bisects the planes of the optic axes visible through the contiguous faces, p ; one of the optic axes is in the centre of the field of the microscope, while the centre of the figure lies about 42° away towards the pole c . The figures are distinct only near the horizontal contour of the crystals; farther inwards they are distorted owing to the wedge

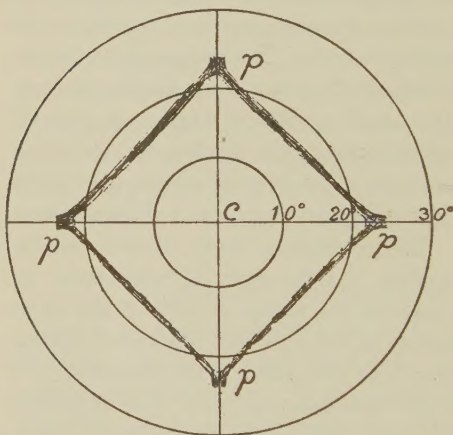


FIG. 1.—Stereographic projection of the 'light-figure' of Schwartzembergite.

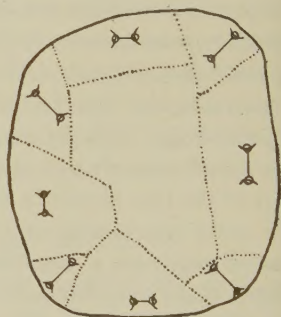


FIG. 2.—Crystal of Schwartzembergite showing division into sectors of different optical orientation.

shape of the section traversed and to the overlapping of different sectors. In the centre no figure is visible, and little variation in the intensity of the transmitted light is noticeable on rotation of the nicols. An approximate determination of the refractivity was obtained, viz. 2.35, by noting the deviation experienced by light traversing the prism formed by a pair of large faces meeting in the horizontal edge.

It is surprising that the same crystal should in different sectors show biaxial interference-figures of such widely different angular width. Inside the crystal the angles reduce to about 16° and 28° . These observations are not in accord with Bertrand's, and it may be questioned whether he

really examined schwartzembergite; his observations agree with the characters of matlockite.

The curious nature of the morphological characters indicates that in these crystals the intermolecular repulsive forces which prevail in liquids and appear as surface tension are comparable with the intermolecular attractive forces which are responsible for the growth of rigid crystals. Schwartzembergite is therefore one of the links connecting liquid crystals with plane-faced crystals.

Chemical Composition. (G. T. P.)

The material used in the analysis consisted of clear transparent fragments of large crystals from the specimen (86453) from San Rafael, Chili. It was carefully picked over under the lens and separated as far as possible from adhering gypsum, traces of which, however, doubtless remained, as shown by the fractional percentages of lime and sulphuric acid obtained in the analysis.

The results of the analyses are as follows:—

	I.	II.	III.	IV.	V.	Mean.
Pb . . .	75.15	75.07	74.98	—	—	75.07
Cu . . .	—	—	—	—	trace	trace
CaO . . .	—	—	—	—	0.67	0.67
Cl . . .	—	—	—	8.02	7.91	7.96
I . . .	—	—	—	8.54	8.73	8.64
SO ₃ . . .	—	—	—	—	0.47	0.47
O and loss .	—	—	—	—	—	(7.19)
						100.00

The weights used in the analyses were 0.4189, 0.4411, 0.5671, 0.6631, and 0.7336 gram respectively. The specific gravity, as determined with the pycnometer on 0.8851 gram of material, is 7.39.

For one of the determinations of lead the mineral was decomposed with sulphuric acid: in the other analyses it was fused with sodium carbonate. The iodine in the water-extract was determined in the usual way by liberating with nitrose, absorbing in carbon bisulphide, and titrating with sodium thiosulphate.

If, as in the previous analyses of Domeyko and Liebe, the iodine and chlorine be considered to be present as iodide and chloride of lead, the above result of the analyses may be interpreted as follows under I, for

comparison with which are given under II and III respectively the results of the previous analyses of Domeyko and Liebe:—

	I.		II.		III.
	(Prior.)		(Domeyko.)		(Liebe.)
PbCl ₂	31.17		22.8		11.40
PbI ₂	15.68		18.7		30.89
PbO	48.29		47.1		48.92
CaO	0.67		—	PbSO ₄	5.51
SO ₃	0.47		2.5	PbCO ₃	1.88
	—	CaCO ₃	1.7	Sb ₂ O ₃	0.91
	96.28	Fe ₂ O ₃ + Al ₂ O ₃	1.6		—
		Silica, &c.	3.7		99.51
			98.1		

The loss of nearly four per cent. could not be accounted for by the detection of any other constituent of the material analysed. It was for this purpose that so many determinations of lead, &c., were made. The conclusion was finally arrived at that the loss must be due to oxygen and that the iodine was present as iodate and not iodide. This idea was strongly supported by the behaviour of the mineral when heated with hydrochloric acid. It was found that abundant chlorine was given off, easily recognizable by its odour and bleaching effects, even when quite small fragments of the mineral were treated with the acid. Moreover, when the mineral was dissolved in cold nitric acid, there was evidence to show that in the solution the iodine was in the form of iodate and not iodide, for the precipitate produced by silver nitrate was pure white in colour and was easily soluble in dilute ammonia, from which solution, on heating, sulphurous acid precipitated silver iodide insoluble in ammonia.

When the iodine is reckoned as iodate of lead the result of the analyses may be written as follows:—

		Molecular ratios.
PbI ₂ O ₆	18.95	0.034
PbCl ₂	31.17	0.112
PbO	48.29	0.216
CaO	0.67	
SO ₃	0.47	
	99.55	

By the fusion with sodium carbonate it would appear that all iodate

was converted into iodide, for no increase of iodine was obtained by treating the water-extract with sulphurous acid before separating the iodine.

The numbers obtained in the analyses correspond fairly closely to the formula $3(\text{PbCl}_2 \cdot 2\text{PbO}) \cdot \text{PbI}_2\text{O}_6$, representing a molecular compound of iodate of lead with an oxychloride of lead having the composition of mendipite.

It would seem as if the anomalous morphological and optical characters of the mineral had a direct connexion with its abnormal chemical composition.

*On Fermorite, a new arsenate and phosphate of lime and strontia, and Tilasite, from the manganese-ore deposits of India.*¹

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[Read January 25 and June 7, 1910.]

ANALYSES of Indian manganese-ores generally show the presence of small amounts of arsenic. The form in which this constituent occurs was discovered by Dr. L. Leigh Fermor in the course of his investigations of these well-known deposits.² At two different localities crystalline arsenates were found. One of these occurrences is at the Sitapar deposit in the Chhindwara district, Central Provinces. The pinkish-white to white arsenate found there is the new mineral to which we have given the name fermorite. The other locality at which an arsenate was found is Kajlidongri, Jhabua State, Central India. The pale-green arsenate, somewhat resembling apatite in appearance, which occurs at this locality has been found by us to be identical with the tilasite from Sweden described by Sjögren.

Specimens of the arsenates from both localities were presented to the British Museum and constitute for the most part the material used for the investigations, the results of which are given in the present communication.

FERMORITE.

The arsenate from the Sitapar manganese-ore deposit is a pale pinkish-white to white mineral occurring in veins in the manganese-ore, which here consists of a mixture of braunite, hollandite, pyrolusite, and the new mineral sitaparite.

¹ Communicated by permission of the Trustees of the British Museum.

² L. L. Fermor, 'The manganese-ore deposits of India,' *Memoirs of the Geological Survey of India*, 1909, vol. xxxvii.

The physical characters of the mineral have been already partially described by Dr. Fermor, in his elaborate report on the manganese-ore deposits to which reference has already been made. It is translucent with a greasy lustre, and has a rather even fracture and a white streak. No well-crystallized specimens of the mineral were found, but one piece showed three sides of what appeared to be a hexagonal prism.

From this observation and the result of a qualitative analysis showing that the mineral consisted essentially of a phosphate and arsenate of lime, Dr. Fermor was led to suggest that it was isomorphous with apatite. The optical and chemical investigation of the mineral which we have made tend to support this idea.

Physical Characters.

The mineral has a hardness of 5, and a specific gravity of 3.518 (as determined with the pycnometer on 1.1968 grams of material). It is infusible in the Bunsen-flame. Optical examination (G.F.H.S.) showed that it is uniaxial and negative, has a low double refraction, and has a mean refraction very slightly above that of monobromonaphthalene, i.e. about 1.660. One specimen showed three prism-faces which provided rough measurements of 60° .

Chemical Composition. (G. T. P.)

The mineral is readily soluble in hydrochloric acid and in nitric acid. The result of the quantitative analysis is as follows:—

					Molecular ratios.	
CaO	...	...	44.34	...	...	0.792
SrO	...	...	9.93	...	...	0.096
As ₂ O ₅	...	...	25.23	...	...	0.110
P ₂ O ₅	...	...	20.11	...	...	0.142
F	...	...	0.83	...	...	0.044
H ₂ O	...	...	trace			
Insoluble	...		0.08			
			100.52			
Less O for F	...		0.35			
			100.17			

Weight of material used in analysis, 0.9138 gram.

In the analysis the mineral was dissolved in hydrochloric acid, and

the arsenic was precipitated as sulphide, and finally determined as arsenate of magnesia, after oxidation of the sulphide with hydroxyl. The phosphoric acid was determined in the precipitate obtained with ammonia in the filtrate from the sulphide of arsenic. This precipitate was fused with sodium carbonate and silica, and the phosphoric acid in the water extract was determined in the usual way with molybdate, and the lime and strontia in the residue by precipitating as oxalates and separating by treatment of the nitrates with a mixture of alcohol and ether. The fluorine was determined by the Berzelius method as modified by Hillebrand, and is probably too low. No chlorine was detected in the mineral.

The numbers obtained in the analysis correspond fairly closely to the formula $3[(\text{Ca}, \text{Sr})_3(\text{P}, \text{As})_2\text{O}_8] \cdot \text{Ca}(\text{OH}, \text{F})_2$, thus confirming Dr. Fermor's suggestion that the mineral consists to a large extent of the arsenic analogue of apatite.

We have named the mineral fermorite in honour of Dr. L. Leigh Fermor, of the Geological Survey of India, who has contributed so much to our knowledge of the Indian manganese-ore deposits.

TILASITE.

1. *Mode of Occurrence.*

Two occurrences of the pale-green arsenate at Kajlidongri in the Jhabua State are described by Dr. Fermor. One of these is in a vein of quartz and barytes traversing the manganese-ore body, where the mineral is found in rounded crystals up to half an inch in length. The other occurrence is in the north-west spur workings, where the mineral forms the chief constituent of a rock in which it is associated with quartz, spessartite, and braunite.

Specimens of the mineral from these two occurrences, as well as better crystallized specimens which were collected by Mr. E. J. Beer and by Mr. H. J. Winch, the manager of the mine at Kajlidongri, were sent to the British Museum for examination. The result of optical examination and measurements of crystals left no doubt that the green mineral from all these sources was the same.

2. *The Morphological Characters.* (G. F. H. S.)

Although the crystals were fairly distinct in form, yet the determination of the crystallographic characters was for several reasons attended with some difficulty. The crystals were in the first place too large to

admit of convenient manipulation on the goniometer, and it was therefore generally impossible to complete the observations in a zone without at least once re-centring the crystal so as to bring the reflections within the field of view. Again, the faces, as often happens with large crystals, were far from plane, and the reflections of the object-slit took the form of a blur of light extending over several degrees of arc in the field of view of the telescope. Moreover, all the crystals were incompletely developed—omitting the cleavage and parting planes—and it was not always obvious how the observations made on different crystals should be collated.

Altogether twelve crystals and fragments were used in the crystallographic investigation, but the values given in the table below were obtained on only five, the best of them. The whole of them were measured upon a goniometer of the ordinary type with a single, horizontal circle; a few were also measured upon a goniometer with three circles, but little reliance could be placed upon the values found for the azimuthal angles.

The crystals belong to the monoclinic system, and reasons will presently be given for believing that they may be assigned to the clinohedral class of that system, which is characterized by a plane of symmetry, but no axis of symmetry; this class has as yet only a single indisputable representative among minerals, viz. the calcium-zinc silicate, clinohedrite,¹ described by S. L. Penfield and H. W. Foote.

Excluding the complementary forms, altogether twelve forms were observed on the crystals:—

b (010), rather dull, not common.

a ($\bar{1}00$), comparatively bright, not common.

m (110), m_1 ($\bar{1}10$), bright and common; a plane of parting as revealed by striations.

e ($\bar{1}01$), present only as a cleavage-face.

g (021), very dull; only once observed (fig. 5).

p (111), p_1 ($\bar{1}1\bar{1}$), bright and common.

x ($11\bar{1}$), dull; only once observed (fig. 3).

r ($\bar{3}31$), r_1 (331), bright and common; a plane of parting as shown by striations.

o ($\bar{1}31$), rare; conspicuous on only one crystal (fig. 7).

y ($11\bar{2}$),
 z ($15\bar{2}$),
 δ ($1\bar{6}5$),

} all three dull and rare.

¹ S. L. Penfield and H. W. Foote, Amer. Journ. Sci., 1898, ser. 4, vol. v, p. 289.

The morphological constants were calculated from the angles given in the following table, and were found to be

$$a : b : c = 0.7503 : 1 : 0.8391 ; \beta = 120^\circ 59\frac{1}{2}'.$$

Table I. Angles used as basis of calculations.

Form.		Mean Values.	Limits of Observed Values.	No.
<i>mm'</i>	110 : $\bar{1}\bar{1}0$	65° 30'	65° 31'—65° 51'	6
<i>me</i>	110 : $10\bar{1}$	61 4	61 0—61 10	3
<i>mp</i>	110 : 111	27 5	26 56—27 18	4
<i>mp'</i>	110 : $\bar{1}\bar{1}\bar{1}$	60 11	59 30—60 58	3

The indices given above having been severally selected for the forms *m*, *e*, and *p*, those of the remaining forms followed from the measurements, particulars of which will now be given.

g (021). This form appeared only once as a rough face on the crystal represented in fig. 5, and no measurable reflections were obtainable. From the parallelism of the corresponding edges it evidently lies in the zone connecting the faces *p* (111) and *m*₁ ($\bar{1}10$). By adjusting the edges common to *b* and *m*, and to *b* and *g* successively parallel to the vertical spider-line of the telescope of the goniometer when converted into a microscope by the insertion of the auxiliary lens, an approximate value, 59°, was obtained for the acute angle between these edges; the calculated value of the supplement of β is 59° 0 $\frac{1}{2}$ '. The face *g* is defined therefore as the intersection of the zones [$\bar{1}11 : \bar{1}10$] and [010 : 001], and has accordingly the indices (021).

r (331). Three different angles were available for fixing the position of this form:—*re* ($\bar{3}3\bar{1} : \bar{1}01$) observed 69° 50', 69° 54', these being the best values, calculated 70° 15'; *rr'* ($\bar{3}3\bar{1} : 33\bar{1}$) observed 57° 30', 58° 12', calculated 58° 35'; *rm*₁ ($\bar{3}3\bar{1} : \bar{1}10$), observed 10° 40', 10° 56', 11° 0', 11° 25', 12° 26', calculated 11° 31'. Since a plane of parting exists parallel to this form, the complementary form was also observed.

o ($\bar{1}31$). The distance angle measured from the nearest face of the form *m*₁, and the azimuthal angle with regard to the equatorial plane were available:—observed ρ 45° 35', ϕ 31° 50', and ρ 46° 37', ϕ 30° 5'; calculated ρ 45° 44', ϕ 29° 56'.

y (11 $\bar{2}$). This form lies in the zone connecting *m*₁ ($\bar{1}10$) and *e* ($\bar{1}01$), and the angle *m*₁*y* ($\bar{1}10 : 11\bar{2}$) was measured as 80° 33', the calculated value being 80° 15'.

z ($15\bar{2}$). The position of this form was determined by its distance from the nearest face of the form m (110) and the azimuthal angle with respect to the zone me [$110 : \bar{1}01$], the values in the two cases being:— ρ observed $62^\circ 30'$, calculated $60^\circ 47'$, and ϕ observed $42^\circ 0'$, calculated $42^\circ 25'$. The measurements were only approximate, and in the case of the second face of the form no observations were found possible.

x ($11\bar{1}$). The solitary face that was observed of this form (fig. 3) lay in the zone connecting m (110) and y ($11\bar{2}$). A very rough measurement gave 40° as the value of the angle mx ; the calculated value is $45^\circ 10'$.

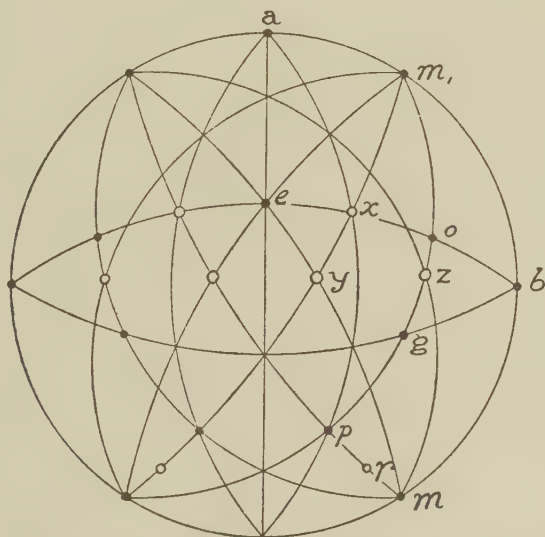


FIG. 1.—Stereographic projection of the crystal-forms of Tilasite. (The circlelets represent the positions of faces beneath the plane of projection but on the opposite side of the centre, i.e. the points where the normals to the faces intersect the upper half of the sphere of projection. Compare J. W. Evans, this Magazine, 1910, vol. xv, p. 401.)

δ ($1\bar{6}5$). The single face that was observed of this form was measured from the nearest face of the form m (110), and a measurement was also made of the azimuthal angle with regard to the equatorial plane, but the values can only be regarded as approximate:— ρ observed $54^\circ 50'$, calculated $55^\circ 18'$; ϕ observed $57^\circ 0'$, calculated $56^\circ 28'$.

In the table below are given the distance and azimuth calculated for the principal forms referred to the face of symmetry b (010) as origin.

Table II. Calculated coordinates of the principal forms.

Form.	Azimuth.	Distance.
b (010)	0° 0'	0° 0'
a ($\bar{1}00$)	0 0	-90 0
m (110)	0 0	57 15
r ($\bar{3}3\bar{1}$)	13 16	-60 $42\frac{1}{2}$
p (111)	27 43	68 $41\frac{1}{2}$
y (112)	-87 0	-67 16
z (152)	-87 0	-25 31
e ($\bar{1}01$)	-54 53	90 0
o ($\bar{1}31$)	-54 53	25 54

a ($\bar{1}00$) is a plane of twinning. Parallel to e ($\bar{1}01$) is a good cleavage, while planes of parting run parallel to r ($\bar{3}3\bar{1}$) and m (110), the former being by far the more prominent, and having the peculiarity that often the planes parallel to one face alone of the form are noticeable.

The crystals are sage- to olive- or apple-green in colour, and translucent to opaque; the lustre is vitreous on the cleavage-face, but otherwise resinous. The hardness is about 5, being somewhat greater than was stated by Dr. Fermor, the massive mineral owing to its readiness to split appearing softer than the crystals.

3. *Description of the Crystals.* (G. F. H. S.)

1. Combination a, m, e, r (fig. 2), the last two being the result of splitting.

This fragment was obtained by fracture from a large crystal. To illustrate its unsymmetrical appearance the back of the fragment has been indicated by dotted lines in the figure. The planes of parting parallel to r are clearly shown.

2. Combination a, m, r, e, x, y, z (fig. 3). Greatest diameter 12 mm.

This crystal is interesting on account of the large number of forms represented. To show its curious shape the faces lying at the back in the figure are indicated by dotted lines. The planes of parting parallel to r are conspicuous, and this face is striated parallel to its intersection with m .

3. Combination b, m, m_1, e, p, p_1, o (fig. 4). Greatest diameter 15 mm.

This crystal is interesting because of the presence of b and the absence of any noticeable planes of parting parallel to r . The back is very rough.

4. Combination $b, m, m_1, p, p_1, o, g, \delta$ (fig. 5). Greatest diameter 23 mm.

A second individual in parallel position penetrates through that drawn, and appears at the left-hand top corner and at the back in the

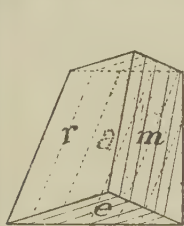


FIG. 2.

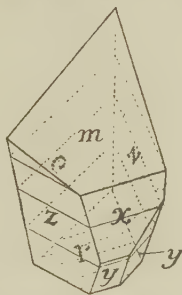


FIG. 3.

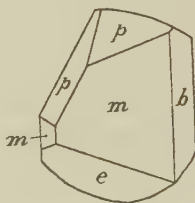


FIG. 4.

Crystals of Tilasite from Kajlidongri, India.

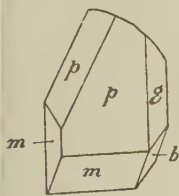


FIG. 5.

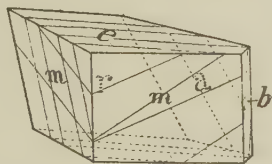


FIG. 6.

Crystals of Tilasite from Kajlidongri, India.



FIG. 7.

position of the figure; the faces o and δ were observed on this individual. The latter and the form g were observed only on this specimen.

5. Combination a, b, m, e, r (fig. 6), the last two being given by fracture. Greatest diameter 20 mm.

The fact that the form a is opposed to the form m is clearly brought out by this crystal. The planes of parting parallel to r are again conspicuous. The other striations on the faces m are in zone with (001) , which has not been observed as a face.

6. Combination m , o , e , r (fig. 7), the last two being the result of splitting. Greatest diameter 25 mm.

This crystal is twinned about a , and very symmetrically developed, and is remarkable for the exceptional prominence of the form o . The striations are parallel to the corresponding face of the form r .

7. Combination e , r . Dimensions, 6 cm. in length, and 4 by 3 cm. in cross-section.

This, which is by far the largest crystal as yet found, is a twin, one individual being much better developed than the other. The plane of composition runs from a re-entrant angle at the top of the crystal on the right hand, down the centre, and inclined to the left at the bottom, reappearing at the back towards the right, and running across to the cleft at the top. The large face e is traversed by planes of parting parallel to r , which forms one side of the cleft referred to. The remainder of the crystal is rough, and only indications of faces are given; braunite occurs in cracks, and gypsum adheres to the surface. This crystal is now in the British Museum.

8. Combination b , m , o , e . Dimensions 5 cm. in length, and 2 cm. in cross-section.

This fine crystal, which is embedded in quartz, is twinned. Both individuals are prismatically developed, the faces of the form m being large, and the plane of composition is approximately perpendicular to the prism zone. The faces b and o are small, and e is, as usual, developed by cleavage. A small simple crystal, 25 mm. in length, also prismatically developed, and showing the faces m and e , the latter by cleavage, is on the same specimen. This specimen belonged to Mr. H. J. Winch.

4. Optical Characters. (G. F. H. S.)

If a section parallel to the cleavage-face e ($\bar{1}01$) be examined in convergent polarized light a biaxial interference-figure with large axial angle is visible, the 'eyes' being outside the field of view. Owing, however, to the imperfect transparency of the crystals no figure is to be discerned, unless the section is ground very thin. The acute bisectrix is perpendicular to the cleavage-face, the double refraction being negative in character, and the plane of the optic axes runs at right angles to the plane of symmetry; $\rho < \nu$, but the colour-dispersion is very small. The following values were obtained by means of an axial-angle instrument for the angle between the optic axes of a small fragment which was ground parallel to e ($\bar{1}01$), when immersed in methylene iodide at 20° C.:—Li 78° 57', Na 78° 16', Tl 76° 10'. Observations were made

on a crystal-face with a small refractometer, and approximate measurements obtained of the principal indices of refraction:— $a = 1.640$, $\beta = 1.660$, $\gamma = 1.675$. The value of $2V$, the angle between the optic axes, calculated from the refractive indices is $83^\circ 24'$; while the observed value given above, viz. $78^\circ 16'$, corresponds to a value of $2V$ of $82^\circ 44'$, the refractive index of methylene iodide being taken as 1.7381. Considering the rough nature of the observations, the agreement is very satisfactory. The type of symmetry determined from the morphology of the crystals would lead us to expect an interference-figure characterized by horizontal dispersion, but none was observed; in an interference-figure with such a large angle between the optic axes, however, it would need to be very pronounced to be noticeable.

Dr. Fermor says in his report, 'One of these brushes indicated in a section in which the angle between the two sets of cleavage was 60° , that the optic axial plane lies from acute angle to acute angle of the cleavage rhombs.'¹ The two sets of cleavage referred to are the planes of parting parallel to the two faces of the form r ($3\bar{3}1$), the calculated value of the angle between the edges in which these faces intersect the cleavage plane e (101) being $61^\circ 45'$, and the optic axial plane meeting the cleavage-face in a direction which is parallel to the bisectrix of the acute angle between the edges mentioned.

5. *Polar Characters, and Crystalline Symmetry.* (G. F. H. S.)

That the face a , when it occurs, is always found on the side of the crystal remote from the faces of the form m , and that while m is a prominent form, r ($3\bar{3}1$) is no less conspicuous on account of the well-marked planes of parting parallel to the faces composing it, point to the conclusion that the mineral has not the full symmetry of the monoclinic system, but should probably be assigned to the clinohedral sub-class. Since this class has no centre of symmetry, the crystals should, if this view be correct, display signs of polarity.

Tests were, therefore, made for electrical polarity by means of Kundt's well-known apparatus. Several crystals were carefully heated, and while cooling were dusted with a mixture of red lead and sulphur blown through a sieve. In every instance there was a distinct difference between the appearance of the side of the crystal on which a occurred and that opposite to it, the former being positively electrified, and therefore yellow in colour, and the latter negatively electrified, and therefore red in colour.

With the solitary exception of the form b (010), parallel faces on a

¹ L. L. Fermor, loc. cit., p. 220.

crystal possessing the symmetry of the clinohedral sub-class of the monoclinic system belong to different forms, but granted that the forms *a* and *m* are opposed to one another no difficulty was experienced in deciding from a study of the habits of the crystals examined to which of the pair of complementary forms any particular face should be assigned, and the proper signs have accordingly been allotted to the indices in the list of forms compiled above (p. 87).

6. Chemical Composition. (G. T. P.)

The mineral is easily fusible in the blowpipe-flame; and is readily soluble in hydrochloric acid and in nitric acid. Heated in a glass tube with sulphuric acid or with potassium-hydrogen sulphate it gives off hydrofluoric acid which etches the tube. The material used in the analysis was taken from a mass in quartz, and, as it was unaccompanied by any other mineral, it was exceptionally pure. It was dissolved in hydrochloric acid and the arsenic was precipitated by sulphuretted hydrogen; and finally determined as magnesium arsenate. The phosphoric acid in one analysis was determined in the slight precipitate obtained with ammonia, which was fused with sodium carbonate and silica; in the second analysis it was determined in a measured portion of the filtrate from the sulphide of arsenic, the lime and magnesia being determined in the remainder after removal of the phosphoric acid by means of tin. The fluorine was determined by fusing with sodium carbonate and silica, according to the method of Berzelius as modified by Hillebrand.

The numbers obtained in the analyses are given under I and II, and under III for comparison are given the results of Mauzelius's analysis of tilasite (fluor-adelite) from Sweden:—

	I (India).		II (India).		Mean.	Molecular ratios.		III (Sweden).			
As ₂ O ₅	...	50.45	...	50.25	...	50.35	...	0.219	...	50.91	
P ₂ O ₅	...	0.32	...	0.54	...	0.43	...	0.003	...	trace	
FeO	...	0.55	...	—	...	0.55	...	0.008	...	0.14	
MnO	...	—	...	—	...	—	...	—	...	0.16	
CaO	...	25.62	{	...	25.75	...	25.68	...	0.459	...	25.32
SrO	...			...	0.06	...	0.06	...	—	...	—
MgO	...	18.30	...	18.38	...	18.34	...	0.458	...	18.22	
F	...	7.18	...	—	...	7.18	...	0.379	...	8.24	
H ₂ O	...	0.73	...	—	...	0.73	...	0.040	...	0.28	
Insoluble	...	0.11	...	—	...	0.05	...	—	...	Cl 0.02	
										Na ₂ O 0.29	
						103.37				103.58	
		Less O for F				3.02				3.47	
						100.35				100.11	
		Specific gravity				3.77				3.28	

The weight of material used in analysis I was 1.0367 grams, and in analysis II 0.9502 gram. The specific gravity (3.77) was determined with a pycnometer on 1.2048 grams of material.

7. Identity with Tilasite.

A fluo-arsenate of magnesium and calcium with very similar composition has been described under the name tilasite by H. Sjögren;¹ it occurs with berzeliite and calcite in the manganiferous dolomite at Långban, Sweden. If the results of the analysis made of tilasite by R. Mauzelius (under III) be compared with those of the mineral considered in this paper (I and II), the similarity of the two will be obvious.

The numbers obtained in the analyses correspond to the formula $(\text{MgF})\text{CaAsO}_4$, the close agreement in the numbers for lime and magnesia in the material from the two widely distant localities indicating that in this mineral these earths are not isomorphously replaceable, but occur in definite proportions.

The tilasite from Sweden was found massive and granular, and showed no signs of crystal form; this character may conceal a slight want of homogeneity, which would account for the perceptibly lower specific gravity. It displayed one distinct cleavage, which Sjögren calls *A*, and at least three others less distinct, which he calls *B*, *C*, *D*. The colour is grey, tinged with violet, and the lustre resinous, but vitreous on the cleavage-surfaces. The colour differs from that of the Indian mineral; the tinge of violet is no doubt due to the presence of manganese.

It would be anticipated that the cleavage plane *A* would correspond to the cleavage *c* ($\bar{1}01$) found in the Indian mineral, and this supposition is confirmed by the optical characters. Sjögren states that a thin section parallel to the plane *A* displays in convergent light a biaxial interference-figure with wide axial angle, the optic axes lying outside the field of view of the microscope, and that the acute bisectrix is nearly perpendicular to this plane, and the double refraction is negative. Sections of the Swedish mineral were cut at right angles to both the acute and the obtuse bisectrices, and the axial angles $2H$ (acute) = $99^\circ 50'$ and $2H$ (obtuse) = $111^\circ 40'$ were measured by Sjögren in poppy-oil of refractive index 1.4789. From these observed angles for yellow light the actual angle between the optic axes, $2V$, and the mean refractive index, β , may be calculated; they are $85^\circ 31'$, and 1.667 respectively. Con-

¹ H. Sjögren, Geol. För. Förhandl., Stockholm, 1895, vol. xvii, p. 291.

sidering the necessarily approximate nature of the observations, the agreement is satisfactory with those found for the Indian mineral.

Sjögren found that the cleavage plane *B* intersected the plane *A* in an edge which made an angle of 30° with the trace of the plane of the optic axes, and met the plane perpendicular to the obtuse bisectrix in an edge which made an angle of 19° with the trace of the plane of the optic axes. The corresponding angles calculated for *r* ($3\bar{3}1$) are $30^\circ 52\frac{1}{2}'$, and $21^\circ 51'$. The plane *B* is therefore the plane of parting *r*.

Again, he found the corresponding angles for the plane *C* to be 34° and 28° . These angles calculated for *m* (110) are $38^\circ 11'$, and $35^\circ 7'$. The differences, though larger, are still within the range covered by errors of observation.

According to Sjögren the cleavage-plane *D* intersected the plane *A* in an edge which was nearly at right angles to the trace of the optic axial plane, and was not observed at all in the section cut perpendicular to the obtuse bisectrix. It would appear, therefore, to correspond to the face *b* (010), but no such cleavage or plane of parting was noticed on the Indian arsenate. There was, however, on a rough part of the crystal represented in fig. 3 a suspicion of a cleavage parallel to *x* ($1\bar{1}1$). This would intersect *e* ($\bar{1}01$) in an edge at right angles to the trace of the plane of the optic axes; but on this assumption we must suppose that it was not noticeable in the section at right angles to the obtuse bisectrix which Sjögren examined.

The concordance in physical and chemical characters, as far as the former were developed, clearly indicate the identity of the fluo-arsenate described in this paper with the tilasite from Sweden.

A similar arsenate (adelite), with hydroxyl in place of fluorine, has also been described by Sjögren; it occurs at Långban, and also at Nordmark and Jakobsberg, but its physical characters are quite distinct from those found for either tilasite from Långban or the present mineral.

On the crystalline form of nitrogen sulphide.

By G. F. HERBERT SMITH, M.A., D.Sc., F.G.S.

Assistant in the Mineral Department of the British Museum.

[Read June 7, 1910.]

IN the course of an investigation¹ of the atomic weight of nitrogen Mr. F. P. Burt, of University College, London, prepared by the following process crystals of nitrogen sulphide, N_4S_4 , surpassing in purity any that had been previously obtained. The nitrogen sulphide was recrystallized from benzene, washed with carbon disulphide to remove as much sulphur as possible, and finally washed with a little cold benzene. The product was powdered on a porous tile, and kept in a desiccator with calcium chloride and cocoa-nut charcoal until it no longer smelt of benzene. It was then sublimed *in vacuo* over silver gauze heated to 100°C . in a steam-jacket, by which means the absence of liquid or gaseous inclusions and of free sulphur in the sublimate was assured.

Measurements of crystals of this substance have hitherto only twice been recorded. Sixty years ago J. Nicklès² as the result of some comparatively rough observations—the values of the interfacial angles being given to half degrees only—concluded that the symmetry was orthorhombic and hemimorphic.

More than half a century later E. Artini³ showed that the crystals are really monoclinic in symmetry, though nearly orthorhombic in angles, and found the following fundamental constants:—

$$a:b:c = 0.8806:1:0.8480; \beta = 90^\circ 40'.$$

Five forms were observed (100), (001), (110), ($\bar{1}01$), (011), of which the first three were well developed, while ($\bar{1}01$), though common, was small, and (011) both small and rare. Simple crystals were met with, but generally they were twinned with respect to ($\bar{1}01$) or (101), in the shape either of distinct individuals or of polysynthetic twins.

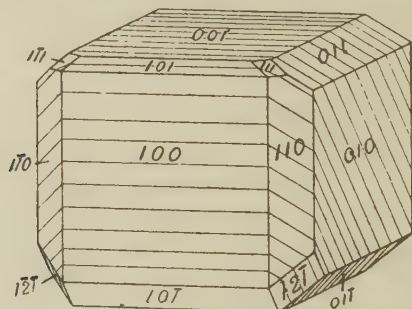
¹ F. P. Burt, Proc. Roy. Soc., London, 1911, vol. lxxxv, pp. 82-98.

² J. Nicklès, 'Sur la forme cristalline du sulfure d'azote,' Ann. Chim. Phys., 1851, ser. 3, vol. xxxii, pp. 420-421.

³ E. Artini, 'Sulla forma cristallina del solfuro d'azoto (N_4S_4),' Rend. R. Ist. Lombardo di Sci. e Lett., Milan, 1904, ser. 2, vol. xxxvii, pp. 864-869; abstract, Zeits. Kryst. Min., 1906, vol. xlii, pp. 68-69.

Measurements made on the present crystals agree closely with those recorded by Artini. By taking the most reliable values the fundamental constants were calculated to be

$$a : b : c = 0.8879 : 1 : 0.8480; \beta = 90^\circ 23'.$$



Crystal of nitrogen sulphide showing twin-lamination parallel to (101).

On all the crystals examined the faces were thickly striated owing to polysynthetic twinning about (101) (see fig.), this face alone being the exception, and the consequent spreading out of the reflected images tended to render some of the observations uncertain. No simple crystals or twin crystals with distinct individuals were observed.

The crystals are orange-red, but their powder is straw-yellow in colour. They are transparent and brilliant when fresh, but lose their lustre on exposure to damp air. In shape they resemble bevelled cubes, and they measure about 1 mm. across. They are much intergrown, but readily separate, the cavity left by a crystal removed being lined with brilliant faces. In addition to all the forms noted by Artini, the following new forms were observed, (010), (101), (210), (111), (121).

Five crystals were measured, but only the most reliable readings are recorded in the following table:—

Angle.	Calculated.	Observed Mean.	No.	Observed Angles.
100 : 001	—	89° 37'	2	89° 36', 89° 38'
100 : 110	—	41 36	2	41 36
100 : 210	23° 56'	23 23	1	—
100 : 101	—	46 31	2	46 31
100 : 101.	46 7	46 0	1	—
010 : 011	49 44	49 44	2	49 41, 49 47
010 : 121	39 6	39 4	2	39 4
010 : 111	58 34	58 55	2	58 45, 59 5

Through the face ($\bar{1}01$) a biaxial interference-figure with wide axial angle, the 'eyes' being far outside the field of view, was visible: the plane of the optic axes is parallel to the plane of symmetry, and the double refraction is strong and positive in sign. Approximate determinations were made of the refractive indices close to the direction of minimum deviation through the prism formed by the faces ($10\bar{1}$) and (001), and the following values obtained:—

2.046, the plane of polarization of the ray being parallel to the face (010).

1.908, the plane of polarization of the ray being perpendicular to the face (010).

The former is therefore the value of the mean, while the latter is near the least, and the acute bisectrix is the greatest axis of the indicatrix. These values are close to those of rhombic sulphur.

A universal goniometer.

By A. HUTCHINSON, M.A., Ph.D.

Demonstrator of Mineralogy in the University of Cambridge.

[Read January 24, 1911.]

THE instrument to be described in the following pages is a goniometer of the suspended type. It is intended primarily for the examination of small crystals, and by its aid all the usual crystallographic and optical determinations can be readily carried out. In its design the attempt has been made to combine efficiency with simplicity and strength of construction, together with adaptability to very various purposes. The instrument was completed in the spring of 1899, and has been in continuous use in the Mineralogical Laboratory at Cambridge ever since.¹ Other instruments of the same general type were in existence at the time,² or have been described during the past twelve years, and several features which were novelties when it was first constructed can no longer lay claim to originality. It has, however, proved itself a serviceable piece of apparatus, and has met with approval from several friends who have examined its capabilities. It is owing to their representations that the following account of it has been prepared in the hope that it may be found useful by other workers.

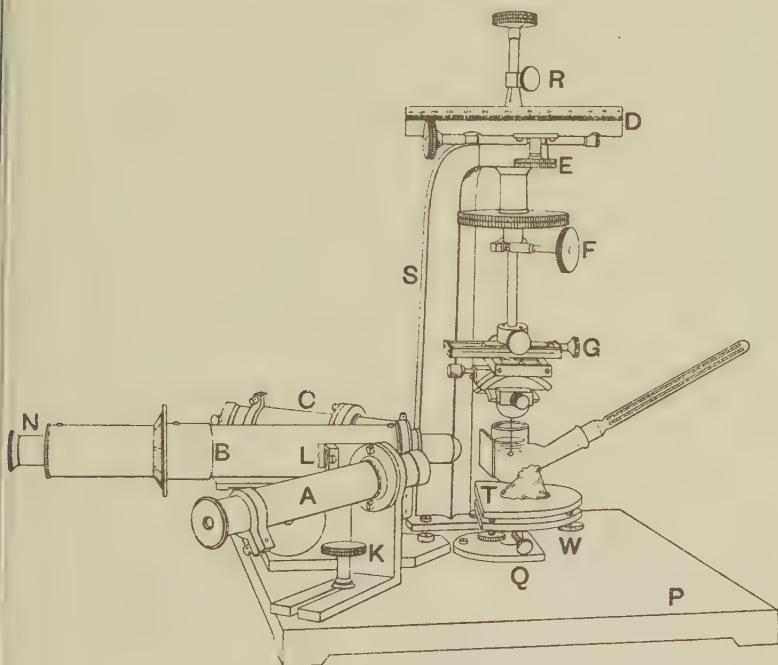
Description.—A circle *D*, five inches in diameter, graduated to $\frac{1}{2}$ degrees and reading by a vernier to minutes is supported by a stout bracket *S*, at a height of ten inches above a flat base-plate *P*, eleven inches square. The circle is provided with a slow-motion attachment, and can be clamped by the screw *E*. A steel rod, which can be clamped at any convenient position by the screw *F*, passes through the centre of the circle and carries, at its lower end, the ordinary centring and adjusting arrangements shown at *G*. A loose collar, which can be clamped to

¹ The instrument was constructed by Messrs. Troughton and Simms, 138 Fleet Street, London, at an approximate cost of £30. It has been briefly described in A. E. H. Tutton's 'Crystallography and Practical Crystal Measurement', 1911, p. 765, fig. 630.

² Vide H. A. Miers, Brit. Assoc. Report, 1894, 654; Zeits. Kryst. Min., 1904, vol. xxxix, p. 223; C. Leiss, Zeits. Kryst. Min., 1899, vol. xxx, p. 363.

the rod by the screw *R*, gives the means of raising the adjusting head and of again lowering it to its former position.

A telescope *A*, and a collimator *C*, are securely clamped to the base-plate in the manner shown at *K*, a number of holes being provided for this purpose at convenient positions. The object-glasses of the telescope and collimator are $\frac{3}{4}$ inch in diameter and about 4 inches in focal length. Their tubes are carried by collars, provided with adjusting screws. An additional lens of $2\frac{1}{2}$ inches focus is also supplied. This can be slipped



Universal Goniometer.

into position in front of the objective of the telescope, thereby converting the latter into a microscope of low power with which the crystal can be examined.

The telescope and collimator are placed at any convenient angle to one another (some angle between 60° and 90° will be found suitable), and the microscope *B* is arranged so that its optical axis bisects the angle between them. The microscope-tube, which is eight inches long, is moved by an ordinary coarse adjustment actuated by a pair of milled heads, one of

which is seen in the figure just below the telescope. At one end it carries a centring nose-piece into which the objectives are screwed, those of $\frac{1}{2}$ inch and of 2 inches focal length will be found most generally useful, but those of $\frac{1}{4}$ inch and of 1 inch focus can sometimes be employed with advantage. At the other end a nicol *N* slips on over the eye-piece; the latter and the nicol-holder are slotted to admit of the insertion of a quartz-wedge or mica-plate. A Bertrand-lens *L* slides into the body of the microscope.

An adjustable table *T*, which can be levelled by the screws *W*, is carried by a steel rod which can be clamped by the screw *Q*; a loose collar clamped to the rod by a screw enables the table to be rotated when supported at any convenient height. On this table can be placed a tank, when it is desired to observe the crystal immersed in a liquid.

Two extra fittings, not shown in the figure, are also provided. Both are similar in shape to that which carries the telescope. One enables a short tube containing a nicol and a condensing lens to be placed opposite the objective of the microscope. The other can be clamped to the graduated circle: at its lower end it carries a collar into which the telescope *A* can be screwed, thus enabling the latter to be supported at the same height above the base-plate ($3\frac{1}{4}$ inches) as the collimator and microscope.

Adjustment of the instrument.—The construction of the instrument is such that all adjustments are under the full control of the observer. They are best made in the following order:—

In the first place the short-focus lens is slipped on in front of the objective of the telescope, which is then placed temporarily in the position to be subsequently occupied by the microscope. A small plate of plane-parallel glass is attached by wax to the crystal-holder. On one surface of this glass plate a fine line has been ruled with a diamond point. By manipulating the screws of the adjusting head this line is brought into coincidence with the axis of rotation of the circle, and the telescope is then arranged to focus it sharply in the centre of the field. The extra lens is next removed from the telescope, and by means of the screws in the collar which carries it, the optical axis of the telescope is made perpendicular to the axis of rotation of the circle. To accomplish this, auto-collimation is employed: the image of the illuminated cross-wires being reflected, first from one side of the parallel glass plate, and then from the other. The illumination of the cross-wires can be effected by means of a special auto-collimating eye-piece, but a plate of glass held in front of the eye-lens in such a way as to reflect into it the light of

A lamp placed on one side of the observer will answer the purpose quite as well. The focusing of the telescope for infinity can also be conveniently carried out at this stage.

As soon as the telescope is in position, the collimator is set up immediately opposite and adjusted until its slit—of the Websky pattern as modified by Miers—is clearly seen on the cross-wires of the telescope. The latter can now be removed and the microscope set up in its place, with the $\frac{1}{2}$ -inch objective of N.A. 0.5 screwed on to the nose-piece. If the Bertrand-lens be now pushed in, it will be found that a bright diminished image of the collimator-signal can be seen. It is important that the optical axis of the microscope should be so adjusted that an object brought into the axis of rotation of the graduated circle should remain steady in the centre of the field of view of the $\frac{1}{2}$ -inch objective during a complete revolution of the circle, and that on introducing the Bertrand-lens a sharp image of the collimator-signal should be seen on the cross-wires. By moving the microscope and by manipulating the screws of the centring nose-piece these adjustments can be effected.

During these operations the plane-parallel glass plate has remained untouched, standing perpendicular to the axis of the collimator, and therefore to that of the microscope also. A reading of the graduated circle is now taken, and it is then turned through some definite angle, 35° say, to the right (counter-clockwise) and there clamped. The telescope is then adjusted by the method of auto-collimation until its axis is perpendicular to the glass plate and is firmly clamped in position, as shown in the figure. The circle is then turned back to its original reading, carrying with it the glass plate, which is now once more standing perpendicular to the axis of the microscope. The final step is to move the collimator to the left of the microscope and adjust it till the image of its signal reflected from the glass plate is seen on the cross-wires of the telescope. When this is the case the optical axis of the microscope bisects the angle between those of the collimator and telescope respectively. To adjust the analyser and polarizer, the condenser should be removed from the tube containing the latter and it should be set up in its stand opposite the microscope. A suitable crystal of quartz or natrolite should then be mounted on the crystal-holder and viewed with the 2-inch objective. When the long axis of the crystal is brought into coincidence with the axis of rotation, a pair of its faces can be set perpendicular to the axis of the microscope and the polarizer and analyser adjusted to give extinction.¹

¹ An excellent account of the method of adjusting a goniometer was given by

The instrument can now be used for any of the following purposes:—

- I. As an ordinary goniometer for the measurement of angles.
- II. As an axial-angle apparatus.
- III. As a Kohlransch total-reflectometer.
- IV. For determining refractive indices by the prism method.

I. *Use as a goniometer.*—The telescope and collimator are employed in the ordinary way. The microscope fitted with a 2-inch objective is useful for examining small crystals, while the reflections from very minute or dull faces can be conveniently observed by means of the $\frac{1}{2}$ -inch objective employed in conjunction with the Bertrand-lens; this combination giving a bright diminished image of the collimator-signal. The 1-inch objective can also be used for the same purpose, if provided with an adapter, to support it at the proper distance in front of the Bertrand-lens.¹

II. *Use as an axial-angle apparatus.*—A fitting similar to that which carries the telescope, but not shown in the figure, is placed on the base-plate. Into it is slipped a tube containing a nicol and a plane-convex condensing lens. This is clamped opposite the microscope which is furnished with a lens of short focus. The $\frac{1}{2}$ -inch objective of N.A. 0.5 will be found the most generally useful; occasionally a $\frac{1}{4}$ -inch, N.A. 0.85, may be employed, but in this case an extra lens should be arranged in front of the condenser provided in the nicol-tube, to render the light more highly convergent.

A crystal plate suspended from the central axis can now be rotated between crossed nicols in convergent polarized light and the value of its optic axial angle measured, either in air, or in any suitable liquid contained in a parallel-sided tank mounted on the table *T*. The crystal-plate is adjusted by means of the telescope and collimator. When it is so placed that it reflects the image of the collimator-signal on to the cross-wires of the telescope it must be perpendicular to the optical axis of the microscope, for this was arranged to bisect the angle between the axes of the collimator and telescope. This adjustment is made with great ease, and permits of the determination of the angle at which an optic axis emerges from any face without the necessity of resorting to auto-

M. Websky, *Zeits. Kryst. Min.*, 1880, vol. iv, p. 545. The essential points have been reproduced by A. E. H. Tutton in his work 'Crystallography and Practical Crystal Measurement', 1911, p. 32.

¹ The use of the Bertrand-lens for this purpose has also been recommended by V. de Souza-Brandão, *Zeits. Kryst. Min.*, 1904, vol. xxxix, p. 583, and by A. Hamberg, *ibid.*, 1907, vol. xlii, pp. 13, 280.

collimation, a great advantage when small crystals are under examination. If an immersion liquid is to be employed, the tank containing it can be rapidly adjusted in the same fashion by rotating the table and by manipulating its levelling screws.

III. *Use as a Kohlrausch total-reflectometer.*—The indices of refraction of quite small crystals can be readily determined by total reflection, and in recent times attention has been repeatedly called to the special advantages of the method originally devised by Kohlrausch.¹ The apparatus now described will be found very convenient for this purpose. The crystal, mounted on a pin, or fastened to some form of rotating holder, such, for example, as that devised by T. Liebisch, is attached to the head *G*, and by means of the telescope and collimator the face to be employed is brought into position. It is then surrounded by a highly refractive liquid contained in a small tank, provided with a thermometer graduated to 1° C., and mounted as shown in the figure.² The plane face of this tank is adjusted to be perpendicular to the axis of the microscope as described above. The front of the $\frac{1}{2}$ -inch objective is now brought as near as may be to the plane surface of the tank without actually touching it, and the Bertrand-lens pushed in. On illuminating the tank from the side with a convergent beam of monochromatic light focused on it by a lens, the limits of total reflection can be observed with great ease. Plates 2 to 3 mm. square will be found amply large enough, and if the face is bright, an area 1 mm. square gives limits which can be readily distinguished. The plate is turned till the limit of total reflection is brought to the cross-wires of the microscope and the circle reading taken. The tank is then illuminated on the other side and the observation repeated. The difference between the two readings gives twice the critical angle.

It has been found that the illumination of the tank can be most conveniently effected by means of a convex lens of about $2\frac{1}{4}$ inches diameter and 5 inches focal length, mounted at the proper height in front of a Bunsen-burner. The latter is screwed to a flat board, which likewise supports an arm, by means of which a bead of sodium carbonate or other salt can be held in the flame. This arrangement enables lens and flame

¹ Vide K. Zimányi, *Zeits. Kryst. Min.*, 1894, vol. xxii, p. 321. A. J. Moses and E. Weinschenk, *ibid.*, 1896, vol. xxvi, p. 150. C. Leiss, *ibid.*, 1899, vol. xxx, p. 363. V. de Souza-Brandão, *ibid.*, 1908, vol. xlv, p. 326.

² The tank can be procured from Mr. H. Helm, 66 Hatton Garden, London. The thermometer is best arranged to enter it at one side, and not, as shown in the figure, at the back.

to be moved readily to the proper position, and it will be found desirable to provide this apparatus in duplicate, one set being used for observations with the light on the right, the other on the left. The visibility of the limit will often be increased if a second lens is interposed between the flame and the tank. This lens may be of about $1\frac{1}{2}$ inches diameter and about $2\frac{1}{2}$ inches in focal length. It is supported on the base-plate of the instrument by a heavy foot.

The best immersion liquid is methylene iodide in which sulphur has been dissolved. Should this attack the substance under examination, a concentrated solution of potassium iodide and mercuric iodide (Thoulet's solution) may be tried. The former is available for substances of which the refractive index does not exceed 1.77.¹ The maximum value of the index obtainable in the case of Thoulet's solution is 1.73.² For substances of which the refractive index is less than 1.65, α -monobromonaphthalene may be employed with advantage. In any case it is essential that the index of the liquid should be determined immediately after the observations on the crystal have been completed. This is best done by finding the critical angle for some substance, such as glass or fluorite, of which the optical properties are accurately known.³ Owing to the rapidity with which the refractive indices of the liquids employed change with temperature, the observations on the crystal and on the control piece should be made at the same temperature, or, if this is impracticable, then at known temperatures. Care should be taken to avoid heating the tank by the proximity of flames, and no time should be lost between the observations. If, however, a double set of illuminating apparatus is available, it will be found easy to complete a set of observations within a temperature range of $0.5^{\circ}\text{C}.$; and, with care, results accurate to two or three units in the fourth place of decimals can be obtained, even in the case of quite small crystals.

¹ It is said that with this liquid an index of 1.83 can be attained; see Schroeder van der Kolk, 'Tabellen zur mikroskopischen Bestimmung der Mineralien,' 1906, p. 13. Personally I have not been able to go beyond 1.785.

² Directions for the preparation of Thoulet's solution and an exhaustive account of its physical properties have been given by V. Goldschmidt, *Neues Jahrbuch Min.*, 1881, Beil.-Band i, pp. 179-238.

³ The following device will be found convenient:—A narrow strip (20 mm. $\times$ 3 mm.) of thin glass of known optical properties is taken, one side polished plane and the other side ground. The crystal is attached at one end of the strip to the ground side, and the strip arranged vertically from the adjusting head *G*. After the critical angle for the crystal has been found, the plate is turned round, till the polished side of the glass becomes the reflecting surface and the critical angle is again determined.

It may be of interest to notice here the effect on the index of refraction of any inaccuracy in setting the limit of total reflection on the cross-wires. This is shown in the following table, in which are given

(1) The critical angle θ (to the nearest minute), for solids of which the indices of refraction range from 1.7500 to 1.5000, when observed in liquids of indices 1.8000, 1.7500, and 1.7000 respectively.

(2) The indices of refraction calculated for these solids on the assumption that θ has been read $1'$ too high in each case.

Index of Solid.	Liquid $\mu = 1.8000$.		Liquid $\mu = 1.7500$.		Liquid $\mu = 1.7000$.	
	θ	Index for $\theta + 1'$.	θ	Index for $\theta + 1'$.	θ	Index for $\theta + 1'$.
1.75	76° 27'	1.75012	—	—	—	—
1.70	70 48½	1.70017	76° 16'	1.70012	—	—
1.65	66 26½	1.65021	70 32	1.65017	76° 4'	1.65012
1.60	62 44	1.60024	66 6	1.60021	70 15	1.60017
1.55	59 26½	1.55027	62 20	1.55024	65 45	1.55020
1.50	56 26½	1.50029	59 0	1.50026	61 55½	1.50023

IV. *Use as a refractometer.*—In order to measure indices of refraction by the prism method, the centring and adjusting head is removed from the goniometer axis and attached instead to the rod which supports the table on which the tank rests. The fitting in which this rod slides is clamped to the base-plate by three screws passing through holes in the base of the fitting. As these holes are somewhat larger than the screws, the fitting can be moved slightly laterally, and we have the means of adjusting this rod so that its axis coincides with the prolongation of the axis of rotation of the circle. The telescope is removed from its holder and screwed into the extra fitting which can be clamped to the upper edge of the disk which carries the graduated circle. The collimator is left in position. On turning the circle, the telescope can be adjusted by means of the collar to view the collimator-signal. The crystal can now be mounted on the head G , adjusted, and rotated until it is in the position of minimum deviation. The amount of the latter is then determined in the ordinary way by means of the telescope.

The utility of the instrument can be further increased by the addition of two accessories—a micrometer eye-piece for the microscope, and a cover circle to be clamped to the axis.

A convenient form of micrometer-ocular can be made by substituting

for the cross-wires of the microscope eye-piece a glass plate ruled with two systems of lines at right angles to one another and 0.1 mm. apart. Every fifth line is ruled stronger than the rest, and every tenth line stronger still. The two lines which intersect at the centre are made particularly distinct, and serve instead of the cross-wires.¹ The field of view, which in the eye-piece supplied is 15.4 mm. in diameter, is thus divided into small squares, and by their aid the angular position of an eccentrically placed image can be determined.

The addition of Stöber's circle, as constructed by the firm of Fuess at Steglitz, converts the instrument into a two-circle goniometer.² It is readily clamped to the central rod, and by a slight alteration it is possible to arrange a pivot to support it underneath, thereby increasing its stability.

In conclusion, it may be pointed out that besides fulfilling the purposes for which it was designed, this instrument lends itself readily to the exigencies of experimental work, for any other apparatus which it may be found desirable to employ in connexion with a graduated circle can be speedily clamped to the base-plate in any position required, and can be as easily removed.

¹ Similar eye-pieces suitable for use with petrological microscopes are supplied by Messrs. J. Swift & Son, 81 Tottenham Court Road, London, and will be found useful for a variety of purposes.

² F. Stöber, 'Ueber ein einfaches Theodolitgoniometer,' Zeits. Kryst. Min., 1898, vol. xxix, p. 25.

Further remarks on the electrostatic separation of minerals.

By T. CROOK, A.R.C.Sc. (Dublin), F.G.S.

Scientific and Technical Department, Imperial Institute.

[Read January 24, 1911.]

IN a previous number of the Mineralogical Magazine (1909, vol. xv, p. 260), attention was called to a simple electrostatic method whereby, using a stick of sealing-wax and a copper plate, grains of minerals which have a metallic or sub-metallic lustre can generally be separated from those of the more transparent minerals, the former being attracted notwithstanding the fact that they are usually heavier than the latter.

One instance of the utility of this method of separation is that of proving the presence of a small amount of cassiterite grains in a large quantity of zircon. This condition of things is frequently met with in the non-magnetic residue yielded by separation with an electromagnet; for though, as is well known, ferriferous cassiterite is weakly magnetic, it is mostly found in the non-magnetic or practically non-magnetic residue, and in this respect it behaves much like rutile. However strong may be one's suspicion, as the result of observations with the microscope, that cassiterite is present in such a residue, it is as a rule desirable to settle the matter conclusively by chemical tests. But the amount of cassiterite mixed with the zircon may be so small that it is impossible to prove its presence by reduction with the blowpipe.

If, however, we apply the electrostatic method of separation, we find that the cassiterite, being a better conductor than zircon, is the more readily attracted; and in consequence of this fact we can obtain a cassiterite concentrate which yields tin by reduction with the blowpipe quite readily. The writer has been able to prove the presence of cassiterite in this easy manner on several occasions when it would have been difficult to do so without the aid of electrostatic separation.

Another instance in which the writer recently found it convenient to adopt electrostatic separation was in the isolation of a doubtful mineral from a mixture of wolframite and ilmenite occurring in a concentrate

received at the Imperial Institute from the Federated Malay States, and stated to have been obtained at Tekka, Kinta, Perak.

The concentrate consisted of a mixture of heavy minerals, and was first submitted to magnetic separation, by means of which it was divided into four parts as indicated below. The column of figures on the right gives the approximate percentages as found by magnetic separation. The other column gives fuller results, obtained partly by chemical and partly by electrostatic means. These figures will serve to indicate more definitely the nature of the separation required.

		per cent.	per cent.	
1. Highly magnetic	Magnetite	1.5	1.5	
2. Moderately magnetic	{ Ilmenite	53.0	89.0	
	{ Wolframite	35.0		
	{ Doubtful mineral	1.0		
3. Weakly magnetic	{ Monazite			
	{ Tourmaline			
4. Practically non-magnetic	{ Rutile	3.5	9.5	
	{ Zircon			
	{ Pyrite			
	{ Quartz	6.0		
	{ Cassiterite			

The constituent of special interest was the doubtful mineral occurring in very small amount in the ilmenite-wolframite fraction. Its presence was not obvious to the unaided eye, but was evident enough when the material was examined microscopically. Its fairly high specific gravity, together with its optical character—uniaxial and positive, and the fact that it was magnetically more permeable than the monazite, suggested the probability that the mineral was xenotime; but it was considered desirable to prove the matter conclusively by isolating the mineral in sufficient quantity for chemical analysis. This was done by electrostatic separation, the possibility of which was promptly suggested by the fact that the supposed xenotime was light-coloured and fairly transparent, and presumably therefore a bad conductor, whereas the ilmenite and wolframite were known to be good conductors. By aid of the electrostatic method described below, about half a gram of the mineral was isolated in a fairly clean condition, and found by chemical analysis to consist essentially of yttrium phosphate, which established its identity as xenotime.

An alternative method of separation.

When, as in the cassiterite-zircon mixture to which we have referred, there is only a small amount of a good conductor mixed with a large

amount of a bad conductor, it is advantageous to adopt the method of separation already described, using a somewhat flattened stick of sealing-wax (or its equivalent) and a copper plate.

If, however, as in the case of the above-mentioned mixture of ilmenite, wolframite, and xenotime, the amount of the bad conductor is very small, the method of using a stick of sealing-wax is rather tedious. Moreover, if one uses a large plate of ebonite instead, the separation does not succeed very well, owing to the difficulty of regulating the intensity of the charge on the plate of ebonite. Under these conditions it is preferable to attract the grains to a second copper plate which can be charged by a simple electrophorus or other such device.

This second copper plate should have one of its faces coated with a layer of shellac, which should be continued over the edge of the plate so as to form a narrow strip around the margin of the other face. At or near the edges of the shellac-covered face there should be insulating supports, which may conveniently be made of two narrow strips of glass cemented to the plate and coated with shellac.

The mixed grains are now placed on the naked copper plate, precaution being taken to have the plate and grains in a dry state. Over this the second plate is placed with its shellac-covered face downwards and in close proximity to the grains, contact being prevented by the insulating supports. The upper plate can then be charged by means of an electrophorus, and the conductors will be attracted to the shellac-covered face, to which they will adhere. The upper plate is then lifted, and the grains brushed off on to a sheet of paper. By a repetition of this operation a concentrate is obtained which consists chiefly of the bad conductor; and this can be finally cleaned as far as possible by the sealing-wax method, which offers fuller control.

By this method, the charge on the attracting plate can be regulated, and scattering of the grains largely avoided. Moreover, a large surface is presented to the mixture, and the separation is thus expedited. In isolating the xenotime from the mixture described above, two copper plates about 5 inches square were used.

We see, therefore, that electrostatic separation finds definite scope as a laboratory method in mineralogical work, especially as an adjunct to the electromagnet; and that this mode of separation can be applied to mixtures which it is either impracticable or undesirable to separate by the electromagnet or by heavy liquids.

COMMUNICATIONS FROM THE OXFORD MINERALOGICAL
LABORATORY. No. XXI.

*An example of Quartz twinned on the primary
rhombohedron.*

By JULIEN DRUGMAN, Ph.D., F.C.S.

[Read March 21, 1911.]

EXAMPLES of quartz twinned on a face of the primary rhombohedron *R* are extremely rare. Only three isolated examples have so far been recorded. The first was observed by Q. Sella;¹ but as his crystal could not be measured, owing to its position on the matrix, it is of only slight importance as evidence of this mode of twinning of quartz.

The second example was found at Reichenstein in Silesia, and was described by G. Rose.² This specimen showed small rosettes of quartz, which were explained by Rose as being formed of four crystals, viz. a central one with the other three grouped symmetrically round it in twinning-position, each with an *R*-face parallel to one of the *R*-faces of the central crystal, and the composition-plane perpendicular to this face. This description was questioned by several other crystallographers,³ and C. Hintze⁴ gives a résumé of this discussion. It will, therefore, suffice here to mention that the quartz was found to be regularly orientated on calcite, and that it was thought more probable that the apparent twinning-relation of the side-individuals to the central portion was due to this orientating influence of the calcite, for, up to that time, no conclusive evidence of the occurrence of this mode of twinning of quartz had been given. Later, however, the discovery of a measurable specimen by

¹ Q. Sella, Mem. Accad. Sci. Torino, 1858, ser. 2, vol. xvii, p. 321.

² G. Rose, Ann. Phys. Chem. (Poggendorff), 1851, vol. lxxxiii, p. 461.

³ F. Hesse, Neues Jahrb. Min., 1854, p. 306; H. Eck, Zeits. Deutsch. Geol. Ges., 1866, vol. xviii, p. 428; A. Frenzel and G. vom Rath, Ann. Phys. Chem. (Poggendorff), 1875, vol. clv, p. 17.

⁴ C. Hintze, 'Handbuch der Mineralogie,' 1905, vol. i, p. 1857.

V. Goldschmidt¹ led him to reconsider the reasons adduced for and against this twinning in Rose's specimen and to accept it as sufficiently grounded. A theoretical consideration of the general principles of twinning, which is set forth in a second paper,² showed him that this mode of twinning should, in fact, be comparatively important among the modes of twinning of quartz.

Goldschmidt's specimen came from the Grieserenthal, a side-valley of the Maderanerthal in Switzerland. It shows a small, much distorted crystal, tabular parallel to *R*, in close contact with an *R*-face of a much larger crystal, but the triangular etchings on the two have their apices pointing in opposite directions. They are in twin-position, the twinning being by rotation of 180° about the normal to their face of contact, *R*. Goldschmidt's measurements fully confirm this, and so establish the existence of the *R*-twinning of quartz. Here *R* is also the composition-plane, whilst in Rose's specimen the composition-plane is perpendicular to *R*.

The twinned crystal of quartz to be described in the present communication was found in the Esterel Mountains, near Cannes, in the south of France. The rock in which it occurred is a laccolitic quartz-diorite, whose large, zoned andesine phenocrysts have been studied by several petrographers. Michel Lévy³ has published a detailed study of this rock, and has named it 'esterellite'. The size of its porphyritic constituents, as well as their relative numbers, varies very much; some of the more acid portions are crowded with bipyramidal quartz phenocrysts averaging 12 mm. in diameter, but sometimes reaching 15 and even 20 mm. These are found scattered over the surface of the weathered rock in large numbers.

The twinned specimen is of average size, and consists of two nearly equal bipyramids joined parallel to an *R*-face. Above there is a re-entrant angle of $-27^\circ 8'$, and below, in the same zone, a salient angle of $+27^\circ 8'$. Both in mode of twinning and general development it is comparable with the so-called 'butterfly-twins' of calcite, as a glance at the accompanying text-figure will show. The measurements are only approximate, owing to the roughness of the faces, but so far as they go

¹ V. Goldschmidt, 'Quarzzwilling nach $r = 10$,' Min. Petr. Mitt. (Tschermak), 1905, vol. xxiv, pp. 157-166.

² V. Goldschmidt, 'Über die Zwillingsgesetze des Quarz,' tom. cit., pp. 167-182.

³ A. Michel Lévy, 'Sur le porphyre bleu de l'Esterel,' C. R. Soc. Géol. France, 1896, pp. xlvii-xlix; and Bull. Serv. Carte Géol. France, 1897, vol. ix, no. 57, pp. 1-47, pls. I-VIII.

they confirm the truly symmetric position of the two individuals. In the first set of measurements (I) the crystal was coated with celluloid varnish and the readings taken at the positions of maximum illumination. In II and III different sets of cover-glasses were affixed to the faces. The results of the two latter sets of readings show that the cover-glass method is here unsatisfactory, owing to slight projections on the faces.

	I.	II.	III.	Calculated.
A } B } C } D } E } F } A }	104° -27 103 77 26½ 76½	103° 15' -25 50 103 10 76 55 25 25 77 5	104° 45' -26 25 102 0 77 40 25 40 76 20	103° 34' -27 8 103 34 76 26 27 8 76 26
M } E }	—	43° 5'	41° 35'	43° 27'
N } F }	—	43° 45'	42° 0'	43° 27'

It is quite impossible to determine whether the parallel *R*-faces are + *R* or — *R*. From a statement made by Friedel,¹ that above 600° C. quartz shows hexagonal-trapezohedral and not trigonal-trapezohedral symmetry, it may be suggested that in these quartz bipyramids, formed in a molten magma, the pyramid-faces were all of the same nature at the time of crystallization. Further experimental evidence is, however, necessary before this can be finally accepted.

Two other interesting features may be observed in the quartz bipyramids from this locality. Firstly, the frequent repetition of parallel growth in the larger specimens gives rise, very imperfectly it is true, to a rough basal plane formed by a number of apices packed closely together, an occurrence observed in a more perfect manner at some other localities.

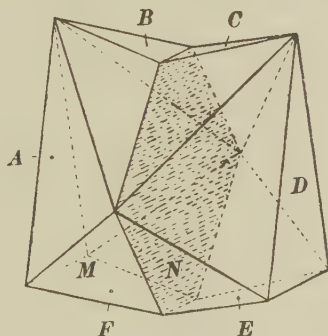
¹ G. Friedel, Bull. Soc. franç. Min., 1902, vol. xxv, p. 112.

Secondly, many of the crystals, which otherwise show no trace of a prism-face, cleave well in this direction. Measurements from such a cleavage-face in the zone with the upper and lower pyramid-faces gave:—

	Measured.	Calculated.
$\bar{R}$ }	38° 0'	38° 13'
∞R }		
R }	38 0	38 13

The cleaved face gave by far the best reflection of the three.

Up to the present, twinning of quartz parallel to R does not seem to have been generally accepted, the only twin with inclined axes that is mentioned in crystallographic works being that in which the twinning-plane is $\xi (11\bar{2}2) = (P2)$, which truncates the edge between two adjacent



Quartz twinned on R ; from the Esterel Mts., France.

(With the exception of a slight overlapping along the edge between the faces E and F , which has been omitted, the figure gives an exact representation of the crystal, about three diameters the natural size.)

pyramid-faces. Goldschmidt has, however, shown that the former is theoretically well founded, and the addition of yet another example to those already known is in support of this. The author hopes to be able to find further examples at the same locality, so as to convince those who hesitate to accept an isolated specimen as sufficient evidence. He is himself, however, convinced, after closely examining this specimen, that it is a genuine twin and not merely a chance intergrowth closely simulating twinning. A further fact supports this: amongst over two hundred crystals from the same locality, he has never found a single case of irregular interpenetration of two individuals. The only irregularities of growth

are due to two or more crystals being joined in parallel position. These parallel growths, already mentioned above, are, in fact, extremely frequent and varied. Sometimes the second crystal only appears as a slightly raised portion on an *R*-face of the other; at other times the two may both be almost fully developed and attached in various ways, but always in strictly parallel position. Some crystals show a deep depression, with roughly hexagonal outline, on a pyramid-face; three alternate sides being parallel to the three sides of the triangular pyramid-face. These too, however, the author was able to prove to have been occupied by a second smaller crystal in parallel position to the first, for one specimen was found in which the parallel growth became detached, leaving a depression of exactly the same shape as those previously observed.

In concluding, the author would like to draw attention to Goldschmidt's papers on quartz-twinning, already mentioned above; and as the laws he establishes include some not generally recognized, a short résumé of them may be useful here, Goldschmidt's numbering and lettering of the classes and types being retained. His third group of 'hetero-twins' more closely approach in their nature the regular growths of two different substances than true twinning, and Goldschmidt only included them in a later paper¹ after he had had the opportunity of examining an actual example of the 'Zwickau' type.

Group I, the common modes of twinning with parallel axes:

A, without rotation (Brazil law).

B, with rotation about the principal axis (Dauphiné law).

Group II, true twins with inclined axes:

C, the well-known Japanese law with $\xi(11\bar{2}2) = P2$ as twin-plane, and the axes inclined at $84^\circ 33'$.

D, *R*-twins with $r(10\bar{1}1)$ as twin-plane, the axes being inclined at $76^\circ 26'$; two types are distinguished:

(i), the Grieserthal type, in which *R* is also the plane of composition. The Esterel example is of this type.

(ii), the Reichenstein type in which the plane of composition is perpendicular to *R*.

E, twin-plane $d(10\bar{1}2) = -\frac{1}{2}R$, the axes being inclined at $64^\circ 50'$. Only once observed² (Sardinian law).

¹ V. Goldschmidt, 'Über Quarz,' Zeits. Kryst. Min., 1908, vol. xliv, pp. 407-416.

² Q. Sella, Mem. Accad. Sci. Torino, 1858, vol. xvii, p. 323.

Group III contains two examples of hetero-twins, which are accepted by Goldschmidt as theoretically possible :

F, Zwickau law of Jenzsch¹; the zones $[mr]$ and $[mz]$ coincide, and the principal axes are inclined at $47^{\circ} 43'$.

G, Zinnwald law of Jenzsch¹; m and r coincide, and the principal axes are inclined at $38^{\circ} 13'$.

If these can all be accepted, and the theoretical considerations adduced by Goldschmidt make them highly probable, twinning parallel to R should be of comparatively frequent occurrence, and the discovery of still further examples should be merely a question of time.

The author wishes to thank Professor Bowman most heartily for allowing him the use of the laboratories at Oxford to carry out the practical work in connexion with this paper, and also for his valuable suggestions.

¹ G. Jenzsch, Ann. Phys. Chem. (Poggendorff), 1867, vol. cxxx, p. 597 ; 1868 vol. cxxxiv, p. 540.

Notes on Cassiterite in the Malay Peninsula.

By J. B. SCRIVENOR, M.A., F.G.S.

Geologist to the Federated Malay States Government.

[Read March 21, 1911.]

THE following notes on some peculiar forms of cassiterite found in the Malay Peninsula will, it is hoped, prove of interest and an addition to our knowledge of the mineral.

Magnetic Cassiterite.

It is now well known that the most effective method of separating wolframite from cassiterite on a commercial scale is the electromagnetic process, which, in theory, lifts all the wolframite from the ore and leaves a concentrate of cassiterite. In practice, however, the separation is rarely, if ever, perfect; and it has been possible for the writer to obtain some interesting information bearing on the point, the most valuable being the discovery of a few specimens of cassiterite that may be termed magnetic in that it can be lifted by an electromagnet.

The mineral in question was found on the land of the Kinta Tin Mines, Ltd., at Gopeng, Perak, occurring as small boulders of cassiterite and quartz in stiff clays believed to be of Permian age. The specimens had attracted notice on account of their peculiar appearance, and the presence of tin had been recognized by Mr. F. Douglas Osborne and Mr. Master, of whom the latter gentleman submitted material to the writer for examination.

The mineral is almost black, having but an obscure tinge of brown, and it shows no crystal outline in the hand-specimens. The streak is dark brown, and a thin section under the microscope shows a mass of minute zoned crystals of cassiterite, the zones being opaque and vandyke-brown. In the translucent zones a pleochroism from vandyke-brown to deeper vandyke-brown is pronounced.

Some of the cassiterite was carefully freed from quartz and analysed. The percentage of tin was only 68, a very low figure for cassiterite, and it was established that iron was the chief impurity. A trace of titanium

was suspected, and subsequently confirmed by Dr. G. T. Prior. The specific gravity is 6.781, as determined by Mr. W. Campbell Smith.

The abundance of iron in this mineral doubtless explains its most interesting feature, which is that fragments greater than 60 linear mesh to the inch and less than 30 linear mesh were lifted by a small electro-magnet using $2\frac{1}{2}$ amperes.

It has been the writer's custom for some time to clean samples of detrital tin-ore by means of the electromagnet, and he has noticed that it is not uncommon for occasional grains of cassiterite to be lifted together with the magnetic mineral impurities. It is possible, of course, that some of these grains, like the Gopeng mineral, are lifted because of a high percentage of iron present in chemical combination, but in the majority of cases the behaviour and appearance of the grains make it plain that they are attracted because of enclosed iron oxide or ilmenite. The amount of cassiterite lifted by an electromagnet is, in the writer's experience, very small in proportion to that which is not attracted, and of no importance as far as the economics of tin-ore are concerned, but as an abnormal form of cassiterite, this Gopeng mineral is of some interest. Specimens have been presented to the British Museum of Natural History.

Replacement-pseudomorph of cassiterite and tourmaline after an hexagonal mineral.

In January, 1911, the writer and Mr. W. M. Currie, General Manager of the Pusing group of mines, in the Kinta district, Perak, happened to pass a spot on the Pusing Bharu mine where one or two coolies are generally at work picking out lumps of tin-ore from the worthless stone coming from the puddlers, and Mr. Currie fortunately noticed a heavy brownish mass with a distinct hexagonal form, measuring about $2\frac{1}{2}$ inches in length and $1\frac{3}{4}$ inches in breadth. The writer examined the specimen later, and found that it consisted of a slightly porous mass of greyish-brown granular material that yielded metallic tin on fusion with potassium cyanide. The hexagonal mass was cut in half and the cut surfaces ground smooth, when it was seen that the granular material showed lines suggesting layers of deposition, and crossed by other lines suggesting veins. A small portion of the specimen, powdered and examined under the microscope, showed that the seemingly granular material consisted of very minute grains of cassiterite together with abundant minute prisms with the characteristic strong absorption of tourmaline and terminations recalling the rhombohedral terminations of the same mineral.

As all the ore at Pusing Bharu is won from beds of clay above the Kinta limestone, none having been found as yet actually in the limestone, one is led to conclude that in all probability this is an example of cassiterite and tourmaline, rapidly deposited from vapour and solution, replacing a crystal of quartz, but no trace of the pyramid-faces are preserved. The prism-faces show striations, but these are oblique and caused by the lines of growth seen in the section.

This specimen, which Mr. Currie has presented to the British Museum of Natural History, may be regarded as analogous to the well-known replacement pseudomorphs of cassiterite after orthoclase, found in Cornwall. It does not resemble the so-called 'silicate of tin' or oxide of tin pseudomorphous after quartz described by Mr. J. H. Collins.¹

Finely granular tin-ore from Siputeh, Kinta, Perak.

In 1910 Mr. W. M. Currie submitted to the writer some pieces of light-brown stone, found in the mine of the Siputeh Tin Mining Co., Ltd., that would have been thrown away as worthless had they not attracted attention by reason of their weight. They were irregular in shape, and contained, in some cases, particles of quartz. The specific gravity of two specimens without quartz was found to be 5.195 and 5.226 respectively. One specimen weighed about 30 grams. A thin section under the microscope showed that the stone consisted of a mass of very minute granules and prisms which under a $\frac{1}{12}$ -inch objective were found to be optically positive and to have straight extinction. A specimen of known cassiterite ground to the same fineness exhibited similar interference-colours, and this, combined with the fact that the stone when fused with potassium cyanide yielded metallic tin, leaves little doubt that the mineral consisted of extremely minute prisms and grains of cassiterite, much smaller than any of the fibres from 'wood-tin' that have come under the writer's notice.

Subsequently, Mr. Currie found specimens in which this finely granular ore could be seen passing into easily recognizable crystalline tin dioxide, and it would seem that the minute structure of the mineral is due to rapid deposition from vapour or solution.

Specimens of this Siputeh ore have been presented to the British Museum of Natural History, and Dr. Prior informs the writer that the specimens in the collection most resembling it are those of 'wood-tin' from Mexico and Bolivia.

¹ J. H. Collins, *Mineralogical Magazine*, 1880, vol. iv, p. 115.

*On the relation between Rathite, Rathite α , and
Wiltshireite.*

By R. H. SOLLY, M.A.

[Read March 21, 1911.]

AT the Society's Anniversary Meeting of November, 1903, I exhibited and gave an account of an unnamed crystal from the dolomite of the Lengenbach quarry in the Binnenthal, Switzerland. In the notice of this meeting, as given in 'Nature' of December 10, 1903 (vol. lxi, p. 142), this mineral, which could not be identified with any of the sulpharsenites of lead previously described, is referred to as follows:— 'One of these [black minerals with metallic lustre] is oblique with $\beta = 81^\circ 11'$, $(100), (101) = 40^\circ 7'$, $(010), (111) = 55^\circ 26'$; it has a perfect cleavage (100), and, like livingite, exhibits no oblique striations on the planes in the zone $[100, 001]$.'¹ Owing to lack of material, the chemical composition and specific gravity of this apparently new mineral could not be determined. Later, in a list of unnamed minerals, which I supplied to Mr. L. Desbuissons for incorporation in his book 'La Vallée de Binn' (Lausanne, 1909, p. 65), the mineral in question is referred to as: 'Cristaux gris de plomb obliques (Rathite α)— $\beta = 81^\circ 11'$ —pas de stries de macles (*Nature*, 1903).' I suggested the term rathite α on account of the close similarity of the interfacial angles, habit, cleavage, and streak to those of rathite.

These observations escaped the notice of Professor Lewis; and the crystal, also from the Lengenbach quarry, described by him in 1910 under the name wiltshireite² is clearly the same substance as that examined by me in 1903. He makes no mention of the close relation which exists between the angles of his crystal and those of rathite.

Since 1903 I have thought that rathite is, like dufrenoyite,³ oblique and not rhombic; but I have postponed publishing anything on this

¹ $[100, 001]$ is a misprint for $[100, 010]$ —the prism-zone.

² W. J. Lewis, 'Wiltshireite: a new mineral,' *Nature*, 1910, vol. lxxxiv, p. 203; *Phil. Mag.*, 1910, ser. 6, vol. xx, pp. 474-475; *Zeits. Kryst. Min.*, 1910, vol. xlviii, pp. 514-515.

³ R. H. Solly, *Mineralogical Magazine*, 1902, vol. xiii, p. 160.

group of minerals in the hope that I should be able to obtain good oblique crystals for chemical analysis.

The following table of calculated angles shows the remarkably close relation which exists between rathite, rathite α , and wiltshireite:—

Rathite. ¹	Rathite α . ²	Wiltshireite. ³
(010) : (140) = $27^{\circ} 36'$: (120) = $46 \ 16\frac{1}{2}$: (320) = $72 \ 19$	(100) : (210) = $27^{\circ} 26'$: (110) = $46 \ 4\frac{1}{2}$: (130) = $72 \ 12$	(100) : (310) = $27^{\circ} 27'$: (320) = $46 \ 6$: (120) = $72 \ 13$
(010) : (3.11.3) = $37^{\circ} 59\frac{1}{2}'$: (131) = $43^{\circ} 40'$: (373) = $50 \ 49\frac{1}{2}$: (353) = $59 \ 43$: (111) = $70 \ 45$: (313) = $83 \ 21\frac{1}{2}$	(100) : (211) = $37 \ 21\frac{1}{2}$: (533) = $38 \ 1$: (533) = $43 \ 8$: (433) = $43 \ 45\frac{1}{2}$: (433) = $50 \ 13$: (111) = $51 \ 0$: (111) = $59 \ 7$: (233) = $60 \ 5\frac{1}{2}$: (233) = $70 \ 1\frac{1}{2}$: (133) = $71 \ 12$: (133) = $82 \ 40$: (011) = $83 \ 57\frac{1}{2}$	(100) : (522) = $37 \ 33$: (311) = $38 \ 4\frac{1}{2}$: (211) = $43 \ 9$: (522) = $43 \ 53$: (322) = $50 \ 14$: (211) = $51 \ 4$: (111) = $59 \ 7$: (322) = $60 \ 10\frac{1}{2}$: (122) = $70 \ 1$: (111) = $71 \ 16$: (011) = $82 \ 37\frac{1}{2}$: (122) = $83 \ 53$
(010) : (031) = $33 \ 6\frac{1}{2}$: (073) = $39 \ 59^4$: (053) = $49 \ 34$: (011) = $62 \ 55\frac{1}{2}$: (013) = $80 \ 20$	(100) : (503) = $32 \ 35\frac{1}{2}$: (403) = $33 \ 9\frac{1}{2}$: (403) = $39 \ 20$: (101) = $40 \ 7$: (101) = $48 \ 46$: (203) = $49 \ 52\frac{1}{2}$: (203) = $61 \ 58\frac{1}{2}$: (103) = $63 \ 29$: (103) = $79 \ 18\frac{1}{2}$: (001) = $81 \ 11$	(100) : (201) = $32 \ 38$: (502) = $33 \ 14$: (302) = $39 \ 22$: (201) = $40 \ 12\frac{1}{2}$: (101) = $48 \ 47$: (302) = $49 \ 58\frac{1}{2}$: (305) = $61 \ 57\frac{1}{2}$: (101) = $63 \ 35\frac{1}{2}$: (001) = $79 \ 16$: (102) = $81 \ 16$

To sum up:—

(1) Rathite, rathite α , and wiltshireite all crystallize with a striated prism-zone, well-marked dome-faces, and a zone of small pyramid-faces. A face perpendicular to the prism-zone is absent.

(2) They all possess a perfect cleavage parallel to the pinacoid to which in rathite α and wiltshireite the symbol (100) has been assigned; in rathite this is Baumhauer's (001) and my (010).

¹ R. H. Solly, Mineralogical Magazine, 1901, vol. xiii, p. 79.

² R. H. Solly, calculated from the angular elements given in 1903 (loc. cit.).

³ W. J. Lewis, loc. cit. Professor Lewis does not give the angles of the prism-zone, but states that he has observed the presence of these three prism-faces.

⁴ This is near to H. Baumhauer's measured angle (001) : (045) = $40^{\circ} 14\frac{1}{2}'$ for rathite (Zeits. Kryst. Min., 1896, vol. xxvi, p. 595).

(3) The streak of each mineral is chocolate-coloured.

(4) In the prism-zone $[100,010]$ the angles between corresponding planes differ but slightly—the variation not exceeding $11'$.

(5) In the second zone in the above table there is a similarity in the grouping of the faces, with angles differing by only $5'$ — $36'$.

(6) In the third zone the rathite angles $33^\circ 6\frac{1}{2}'$ and $40^\circ 14\frac{1}{2}'$ (measured by Baumhauer) are practically identical with the wiltshireite angles $33^\circ 14'$ and $40^\circ 12\frac{1}{2}'$.

(7) Professor Lewis describes his crystal as a simple one, but from his measured angles $(100) : (522)$ and $(100) : (302)$ it may be suggested that the crystal is twinned with (100) as twin-plane and face of union, since this twinning is common in the oblique rathites. His planes (522) and (302) would then be equivalent to $(31\bar{1})$ and $(20\bar{1})$ respectively, as shown below :—

	Calculated.	Measured (Lewis).
$\{ (100) : (522)$	$37^\circ 33'$	$38^\circ 7'$
$\{ \quad : (31\bar{1})$	$38 \quad 4\frac{1}{2}$	—
$\{ (100) : (302)$	$39 \quad 22$	$40 \quad 11$
$\{ \quad : (20\bar{1})$	$40 \quad 12\frac{1}{2}$	

Cadenabbia, Lake Como.
March, 1911.

The brecciation of mineral-veins.

(With Plates IV–VI.)

By FRANCIS H. BUTLER, M.A., A.R.S.M., L.S.A. (Lond.)

[Read June 13, 1911.]

EXAMINATION of a series of examples of vein-breccias demonstrates that while many have readily explicable characters in common, others differ from ordinary types, and exhibit peculiarities calling for special investigation.

Characters distinguishing vein-breccias from volcanic breccias.—Owing to their situation along zones of fracture or within fissures that have served for the passage of waters charged with mineral matter, the primal constituents of vein-breccias are rarely devoid of signs of alteration, and the cementing material is of secondary origin. In this, among other respects, they differ from volcanic breccias, such, e.g., as the slate-ash rock of Glenridding, Ayrshire, the components of which are all clastic and were simultaneously deposited.

When a volcanic breccia has been subjected to the action of gases, moisture, and mineralizing agents, changes in both cement and included fragments may take place sufficient to render a hand-specimen scarcely distinguishable macroscopically from a vein-breccia. Thus the volcanic breccia at St. Anthony's Chapel, Edinburgh, consists now of partly eroded and much chloritized lapilli cemented by calcium carbonate. It is evident that the original mass was percolated by a fluid such, for instance, as that which lined the vesicles of an andesite at Penmaen, west of Pwllheli, with chlorite, and filled the interior spaces with calcite. Many brecciated mineral-veins can be shown to have been subjected to like changes.

The agency of water in the formation of vein-breccias.—With regard to the origin of brecciated mineral-veins, the question of paramount importance is the part played by underground waters. Shearing and fracture of a rock do not necessarily result in brecciation, as Dickson¹ shows in his account of the pyrrhotite deposits of Rossland, British

¹ C. W. Dickson, Trans. Amer. Inst. Min. Eng., 1904, vol. xxxiv, p. 36.

Columbia, where, in his opinion, dynamic movement doubtless took place under an immense load.

The relationship of water-supply and earth-movements in the formation of vein-breccias.—The earth-movements that have been productive of vein-debris commonly appear to have prepared a way for the passage upwards of cementing material. A specimen of vein-breccia in the Museum of Practical Geology, No. 375, from Ogo Gyfwr, Anglesey, indicates the repeated fracture of lode-quartz, and consequent occupation of many of its cracks by chalybite. Another specimen, No. 374, from Esgair Hir mine, Cardiganshire, originated in the erosion of fragments of slate by waters carrying abundant chalybite. This process was continued by a solution of quartz, which mineral enringed or (as at A, fig. 1) completely replaced them.

Change in the composition of the cementing material of vein-debris can often be shown to be consequent on the reopening of a fissure. In the Perran lode, near Marazion, Cornwall (fig. 2), first a breccia was formed of polygonal pieces of clay-slate with abundant quartz-cement. Later on, chalybite in solution was introduced along a rift betwixt this breccia and one wall of the lode, investing and seaming parts of both.

Messrs. Spurr and Garrey¹ state that in many cases the veins in the Georgetown mining district, Colorado, 'have the nature of rubble-filled fissures in which angular fragments of the wall rocks have been cemented together by ore, thus forming a breccia. By subsequent movements . . . the veins have sometimes been reopened and the ore-cement, above mentioned, brecciated in turn and recemented by pyrite, siderite, . . . or quartz'. The refissuring of the rhyolite-quartz-calcite-breccia of the Original Bullfrog vein, Nevada, ushered in the fresh deposition of quartz with much replacement of rhyolite and calcite thereby.²

Lode-material from Restormel mine, Cornwall (fig. 3), establishes that rising waters charged with silica and doubtless also carbon dioxide³ there attacked massive chalybite in cleavage-directions, converting it into a breccia-like aggregate of rhombohedral fragments with septa formed of well-crystallized quartz, by which their shape is still outlined. Soon after the access of oxidizing agents to the lode the supply of quartz ceased, a slight ferruginous tint being imparted to that last formed. The

¹ J. E. Spurr and G. H. Garrey, Bull. U. S. Geol. Surv., 1904, No. 260, p. 111.

² F. L. Ransome, Bull. U. S. Geol. Surv., 1910, No. 407, p. 99.

³ To the action of some such solution may be ascribed the juxtaposition in certain basalts—that of Rhuda-nan-Gall, Mull, e.g.—of amygdalæ that are composed exclusively of chalcedony and of calcite.

chalybite was then partly dissolved away, partly transformed into limonite and goethite, rhodochrosite where present being similarly transformed into manganite and pyrolusite. In the midst of a patch of goethite may be detected a few lenticular crystals of chalybite that have remained intact. The formation of goethite ($\text{Fe}_2\text{O}_3 \cdot \text{H}_2\text{O}$) later than limonite ($2\text{Fe}_2\text{O}_3 \cdot 3\text{H}_2\text{O}$) may signify diminution in the supply of water to the lode-cavity.

CRUSH-BRECCIAS.

An important class of vein-breccias consists of those formed along the whole extent of a rock that by crushing has been rendered readily permeable to mineralizing waters. For these the term crush-breccias is distinctly appropriate. When metalliferous, they illustrate the dictum of Emmons¹ that ore-deposits are to a large extent actual replacements of crushed country-rock, the vein-materials being substitutes therefor and not mere infillings of open cavities.²

Illustrations of the modes of origin and characters of crush-breccias.—Some veins in the Georgetown mining district, Colorado, described by Messrs. Spurr and Garrey³ afford a good insight into the mode of origin of crush-breccias. They consist entirely of zones of crushed, pulverized, and altered country-rock, differing little from the wall-rock except in being slightly more silicified and kaolinized. For the circulation of underground water these have served as channels in which retardation of flowage has been favourable to the deposition of ore.

The inception of the conglomerate-breccias of the Vermilion Range, Minnesota, as Messrs. Smyth and Finlay⁴ have shown, was due to the fracture of the original massive rocks into roughly rhomboidal blocks by lateral compression.

The Foxdale lode in the Isle of Man rarely takes the course of a simple fissure, but is 'a belt of disturbed "country", with more or less parallel fractures . . . containing brecciated rock, with vein-stuff and ore generally in ribs but occasionally also brecciated.'⁵

¹ S. F. Emmons, Trans. Amer. Inst. Min. Eng., 1888, vol. xvi, p. 808.

² According to A. M. Finlayson, Quart. Journ. Geol. Soc., 1910, vol. lxvi, p. 310, replacement has played only a minor part in the formation of the important deposits that have yielded the bulk of the lead and zinc veins of Great Britain.

³ J. E. Spurr and G. H. Garrey, loc. cit., p. 113.

⁴ H. L. Smyth and J. H. Finlay, Trans. Amer. Inst. Min. Eng., 1895, vol. xxv, pp. 630-633.

⁵ G. W. Lamplugh and W. W. Watts, Mem. Geol. Survey, 'Geol. of the Isle of Man,' 1903, p. 509. The brecciated vein-fillings of the Foxdale, Brow

The Grassington lead-mines, Yorkshire, have furnished a vein-breccia that is simply sandstone of which the polygonal segments are demarcated by a cement of galena precipitated from percolating lode-waters (fig. 4). In lode-stuff from Cronebane mine, Co. Wicklow, we note that slightly disrupted blocks of soft killas have been reunited by seams of galena (fig. 5).

At Sudbury, Ontario, where crushing, shearing, and slickensiding are notable features, the ore-bodies are 'replacements along crushed and faulted zones with only minor indications of open cavities'.¹ The second generation of pyrite in the Witwatersrand auriferous conglomerate, South Africa, has been proved to be a replacement of quartz.²

In the west of England, vein-breccias consisting of courses of fractured tuffaceous rock in various stages of silicification and of replacement by quartz are far from rare. A specimen from near Sourton, Devon, e.g., shows patches of Culm-measures slate isolated by crystallized quartz, the encrusting rings of which must have grown thicker centripetally while the rock slowly underwent dissolution (fig. 6).

A frequent final result of the action of underground waters on the inclusions in a breccia is such a vein-stone as that from Wheal George, near Dittisham, in Walkhampton parish, Devon (fig. 7), namely, quartz-rock largely made up of spheroidal or ovoid aggregates of radiating crystals. In a specimen from Peak Hill, in the same parish (fig. 8), rapid and perhaps one-sided solution of a nucleus of rock has allowed the final crystallization of quartz straight across a central cavity.

FISSURE-BRECCIAS.

In the class of brecciated mineral-veins distinguishable as fissure-breccias, the materials cemented together consist of country-rock dislodged from the walls of open fissures and sometimes also of portions of pre-existing deposits therein.

Assigned modes of production of fissure-breccias.—For the origin of these breccias assigned causes are movement of the walls of veins, overweighting of portions of the walls by accretions thereon, loosening of the bases of mineral-crusts and deposits by decomposition of rock, and molecular pressure occasioned by the crystallization of minerals.³

Leadhills), and Rampgill (Nenthead) lodes, are regarded by A. M. Finlayson, *loc. cit.*, p. 289, as proof of movement since primary ore-deposition.

¹ C. W. Dickson, *loc. cit.*, p. 63.

² R. B. Young, *Trans. Geol. Soc. S. Africa*, 1909, vol. xii, p. 96.

³ See A. W. Stelzner and A. Bergeat, 'Die Erzlagerstätten,' 1904, p. 535,

Emmons¹ regards the fall of fragments into the cavity of a lode as of rare occurrence. Those usually found he considers to be the product of the rubbing or dragging of one lode-wall against the other. He takes the view—on which the consensus of experienced rock-drillers would be of interest—that under the enormous pressure productive of rock-fractures the space between the walls of a fissure must by attrition have been more or less completely filled with rock-fragments and finely comminuted material. Percolating waters, while converting the latter into impure clays, would effect the rounding of the coarser clastic constituents of the fissure-contents.

The substitution of ore and other vein-stuff for the disintegrated and decomposed material in a fissure-cavity no doubt sufficiently explains the occurrence in many lode-breccias of dispersed, rounded or eroded rock-fragments. Without careful scrutiny of the circumstances of their formation, it may be impossible to discriminate betwixt these breccias and those resulting from the passage of mineral-laden waters through rock broken up *in situ*, or crush-breccias.

Illustrations of the modes of origin and characters of fissure-breccias.—Good examples of vein-breccias that have imperfectly filled fissure-cavities are those of Strontian, in Argyllshire, and Wheal Phoenix, Cornwall (fig. 9), consisting respectively of an aggregate of rock-fragments held together by brewsterite and of lamellar portions of crystallized lode-quartz having their free surfaces encrusted with cuprite.

What is really a fissure-breccia modified by the action of lode-waters is the stanniferous and cupriferous breccia-conglomerate of Relistian mine, Gwinear, Cornwall,² frequently described as a congeries of surface-pebbles of quartz and killas.

From J. Carne's³ account of this lode-material we gather that it was a body of pebbles of some 12 feet cube, lying between the outer forks of a quadrifid argillaceous cross-vein (flucan), and commencing at a depth of 75 fathoms. Other pebbles distributed singly or in bunches occurred 4 fathoms above and 5 fathoms below where it was first discovered. Of its components Carne observes: 'The pebbles are generally composed of

and C. G. A. von Weissenbach, 'Abbildungen merkwürdiger Gangverhältnisse aus dem sächsischen Erzgebirge,' 1836, pp. 21–26.

¹ S. F. Emmons, Trans. Amer. Inst. Min. Eng., 1888, vol. xvi, pp. 822–823.

² Greg and Lettsom, 'Manual of the Mineralogy of Great Britain and Ireland,' 1858, p. 357, erroneously give the Wherry mine, Penzance, as the locality.

³ J. Carne, Phil. Trans., 1807, vol. xcvi, pp. 293–295.

hist [*sic*], cemented in some parts by the same substance or chlorite, in others by oxyde of tin, which is generally crystallized, and in some of the crevices there is a little copper pyrites.'

If the formation of the Relistian lode took place long previous to the main denudation of the Gwinear district, the distance of any superficial detritus from the deepest location of Carne's pebbles must have been of far greater extent than his figures indicate. A significant, though negative feature of the lode-material is the lack of fine-grained debris of evident alluvial origin. This one would imagine to be more likely to pass freely into the deep recesses of a rock-fissure than surface-pebbles and sub-angular blocks mostly not less in size than tennis-balls, some being many inches in length.

In the specimens of this breccia-conglomerate at the Museum of Practical Geology the only visible quartz bearing the semblance of a pebble is that occupying a globular space apparently voided by a nodule of killas (A, fig. 10). This, presumably, is one of the 'few pebbles' noted by Carne as 'composed of tin in quartz coated with chlorite.' The other quartz within view is interstitial, and is unmistakably of later origin than the chlorite that has penetrated into and everywhere invested the killas nodules. The killas shows no signs of weathering 'at grass' or of exposure to impact sufficient to develop signs of cleavage. Rounding of the edges of the nodules, as if affected by a solvent, has been generally very complete. In some broken hand-specimens, moreover, the cleavage-planes of several adjoining masses of the chlorite-clad killas may be seen to be approximately parallel, as if they were portions of one original block that had been scotched, segmented, and finally rounded by a liquid erosive agent. Trevascus mine, it may be observed, has yielded a stanniferous vein-stone precisely like that of Relistian, except in the marked angularity of the fragments of killas united by chlorite: clearly no surface-weathering has affected its constituents.

Fallen portions of the hanging-wall of lodes, observes Moissenet,¹ being acted upon by water . . . would become globular, and would sometimes form the nuclei of spheroidal concretionary masses. Miners in the Furness and Frizington districts in the north of England in fact not infrequently come upon water-worn pebbles of haematite imprisoned in cavities (locally 'loffs') in water-courses following cracks or faults in iron-ore, very frequently at the junction of vein- and country-rock.

The 'pebbles' of the Relistian lode-stuff are evidently identical in

¹ L. Moissenet, 'Études sur les filons de Cornwall,' 1874, p. 75.

origin with the 'angular fragments of shist' observed by Carne at a depth of 65 fathoms. They may be safely regarded as having travelled no further than the walls of the lode in their immediate neighbourhood. The history of the rock can, in fact, be but little different from that of a conglomerate in a gold-bearing vein in the Remedios district, Antioquia, Colombia, South America. This 'in all the instances observed', says Halse,¹ 'was evidently formed *in situ*, and probably in the main by the sliding-down of the hanging-wall.' Angles of the larger fragments were 'taken off to some extent by attrition, the rounding process being completed by the later inflow of thermal waters, which also cemented the pebbles together, finally converting the whole into one solid mineral mass.'

The angular inclusions of fissure-breccias.—In British fissure-breccias the presence of definitely angular portions of country-rock is far from rare. Sir W. W. Smyth² remarked of the lode of the Cornelly or Townsend mine in the Isle of Man that it was vuggy and sometimes fragmentary, with sharp, angular country-stone. In a vein-stone from Allenheads, Northumberland (fig. 11) we find angular bits of slaty rock, each with an exterior ring of chalybite—clearly their first investment—dispersed in a quartz matrix. Sir H. T. De la Beche³ specifies nine Cornish mines besides Relistian in which angular fragments of slate were noted in a basis of metalliferous minerals.

Speaking of the Menheniot, Lanreath, and St. Pinnock lead-lodes, Henwood⁴ remarks that the metalliferous portions are now and then separated from the containing country-rocks by bodies of breccia, in which for the most part angular masses of slate are enveloped in successive secretions of quartz, all of more or less radiated structure.

A lead-lode breccia from Wheal Betsy, Mary Tavy, Devon, exhibits sharp-cornered bits of Culm-measures country-slate completely isolated from one another, as a series of parallel sections (figs. 12–15) proves, by crusts of well-terminated quartz crystals. The bits of slate must have been subjected to stress tending to open out cleavage-planes, for the edges of some are serrate, and here and there incomplete longitudinal cracks occupied by quartz are visible. Many indicate by their slight

¹ E. Halse, Trans. Amer. Inst. Min. Eng., 1906, vol. xxxvi, pp. 154–177.

² See G. W. Lamplugh and W. W. Watts, loc. cit., p. 517.

³ Sir H. T. De la Beche, 'Report on the Geology of Cornwall, Devon, and West Somerset,' 1839, pp. 322–323.

⁴ W. J. Henwood, Trans. R. Geol. Soc. Cornwall, 1871, vol. viii, Part I, pp. 712–713.

lateral displacement their former connexion with one another. The appearance of the breccia is such as would be produced by the gradual shifting of the quartz-covered fragmental slate into the lode-fissure, and the filling in of interstices by fresh deposition of quartz crystals.

The detachment and encrustation of angular shreds and strips of country-rock to form a breccia is well exemplified by the slate-quartz-barytes-veinstone of the cross dip-fault breaking the main fault between the Pre-Cambrian and Arenigs at Pont Bren, Aberdaron (fig. 16), and also by the similar slate-quartz-galena lode of the lead-mine near Pont Erwyd, North Wales (fig. 17).

Inferences from characters as to the provenance of angular inclusions.—The dispersal of apparently isolated angular bits of country-rock in breccias such as those just mentioned is a problem requiring elucidation. Their maintenance free in vein-cavities contrary to gravitation until enveloped in cement is no more thinkable than the fabled suspension of Mahomet's coffin in mid-air. Their frequently uneroded and fresh-looking, sometimes partly silicified condition negatives the supposition that they are necessarily the undissolved remnants of vein-debris. Waters capable of dissolving away finely comminuted rock would certainly leave on the coarser portions some definite signs of their destructive action.

The suggestion has been made that when the rock-fragments in fissure-breccias seen in section are seemingly not in contact, but swimming as it were in their matrix—*rari nantes in gurgite vasto*—they yet actually support and are frequently wedged into one another or are nipped between vein-walls.¹

This contention, if approximately true of ore-bearing fissure-breccias, seems doubtfully relevant with respect to such rocks as the brecciated vein at Port Henry, on Lake Champlain, New York, described by Sterry Hunt,² consisting of elongated irregular fragments of hornblende-gneiss from the wall-rock 'completely enveloped in crystallized calcium carbonate'. It provides us, further, with no explanation of the origin and persistence in many fissure-breccias of a mosaic-like arrangement of what are clearly the constituent portions of cross-fractured angular bits of country-rock.

Of some specimens of vein-stone from Huelgoët, in France, it has, for example, been remarked that they contain slaty fragments apparently

¹ A. W. Stelzner and A. Bergeat, op. cit., p. 537; see also Pošepný on the structure of ring-ores, 'The Genesis of Ore-Deposits,' 1902, 2nd ed., pp. 64–65.

² T. Sterry Hunt, 'Mineral Physiology and Physiography,' 1886, p. 237.

separated from one another by slow degrees, and showing the exact way in which these formerly fitted together.¹ Such fragments, having been gradually parted from one another without, as a rule, much alteration of their relative positions, have clearly been prevented from falling far asunder by the interposition of a crystalline cement.

Seemingly Weissenbach's theory that the force of crystal growth—well exemplified in the disintegration of chalk fossils dried after saturation with sea-water, and in the breaking up of rock and mineral specimens by melanterite developed from contained marcasite by atmospheric oxidation and hydration—may be efficacious in providing the angular constituents of vein-stuff does not apply to the fragments in question. We may confidently assert that not until these were bound together by crystal growth as we now see them were they removed from the walls to the body of any vein. Dislocation loose into a fissure-cavity would have subjected them, under the action of gravity, to disarrangement sufficient to prevent any recognition of their relationship, even if, unlike the country-rock inclusions in a breccia from the Devon United mine, Peter Tavy, Devon (fig. 18), they had escaped attack by percolating solvent waters and consequent partial replacement by chlorite, felspar, quartz, and other minerals.

Facts suggesting that brecciation is sometimes independent of earth-movements.—Sir H. T. De La Beche appears to have arrived at the opinion that the degree of brecciation of a lode is dependent entirely on the amount of regional disturbance in which it has participated. The view, however, that the presence of angular fragments of country-rock in vein-breccias is always positive testimony to the shattering effect of earth-movements does not tally with the conclusions suggested by a consideration of characters presented by a goodly number of examples of mine-material.

The fractured appearance of some west of England vein-stones in which there has been considerable leaching-out of country-rock is in favour of the view that occasionally dissolution at a more rapid rate than replacement has occasioned falls of vein-stuff by the withdrawal of support (see fig. 19).

That there is another and more frequent cause of brecciation in mineral-veins, acting quite independently of earth-movements, seems to be indicated by the following facts:—

In the Tavistock district, Devon (see fig. 18), and in Cornwall—in the

¹ J. A. Phillips, 'A Treatise on Ore Deposits,' 2nd ed., by H. Louis, 1896, p. 86.

Revascus mine, for example—the gangue of brecciated country-rock (either Culm-measures slate and shale or killas) may be found extending in thin seams or well-marked bands into the vein-walls, mostly along cleavage-planes, just as far as dislocation or contortion of those planes has been brought about.

When the banding and disturbance of the wall of a brecciated vein does not proceed far into its country-rock, it may with reason be questioned whether either those features or the formation of the breccia should be regarded as the results, direct or indirect, of earth-movements. It can scarcely be argued that the physical changes in the country-rock besides the brecciation of the vein within it might be due to the dragging and rubbing of one vein-wall against the other. The fact that affection of the country-rock is conterminous with the limits of the narrow areas delimited by the intrusive breccia-cement points pretty conclusively to the causation both of it and of the brecciation without differential movement of the vein-walls. Henwood,¹ moreover, has pointed out that thin included slices of rock ('horses') in lodes, i. e. masses lying apart from though 'jointed and cleaved uniformly with the immediately contiguous (country) strata . . . are occasionally penetrated, from either side, by slender strings of the vein-stones'.

It can certainly not be maintained that the banding of killas and other fissile rocks just in the immediate vicinity of lodes is due to a segregation of minerals such as obtains in the foliation of gneiss, for these rocks, except as regards disturbance of the parallelism and cohesion of their original laminae, have generally undergone no marked intrinsic change.

The smallness of the mean percentage volume of the interspaces determined by Sorby to exist in slates—3.6 (Moffat) to 0.24 (Penrhyn)—is opposed to the conjecture that the abundant mineral bands often to be seen in the boundary walls of brecciated veins therein are deposits from absorbed water. Weissenbach, in support of his theory of the disruption of vein-rocks by crystalline force, adduces the breaking-up of loam and clay by the growth in them of crystals of gypsum and ice. Now, Sorby² reckons the volume of the cavities in but slightly compressed clays at 2 or 33, and in Tertiary clays at 28.8 per cent. Crystallization within loam or clay saturated with moisture may, therefore, be regarded as the segregation of particles from a liquid thickened by admixture with

¹ W. J. Henwood, loc. cit., p. 712.

² H. C. Sorby, Quart. Journ. Geol. Soc., 1908, vol. lxiv, p. 228.

nearly twice its bulk of mobile foreign matter. We have here no criterion of the behaviour of solutions occupying the interspaces among the constituents of nearly compact rocks. We lack, also, evidence that rifts in such rocks would be gradually enlarged by accretions on mineral-deposits already filling them until extensive fractures had been produced. Continued accretion on the inner ends of crystals lining the walls of a rift would require the maintenance of a median passage for the free ingress of fresh supplies of the invading mineral—a condition doubtfully compatible with the exercise of disruptive crystalline force. Accretion on the outer ends or bases of the crystals would imply a porosity of the walls of the rift inconsistent with the characters of many country-rocks.

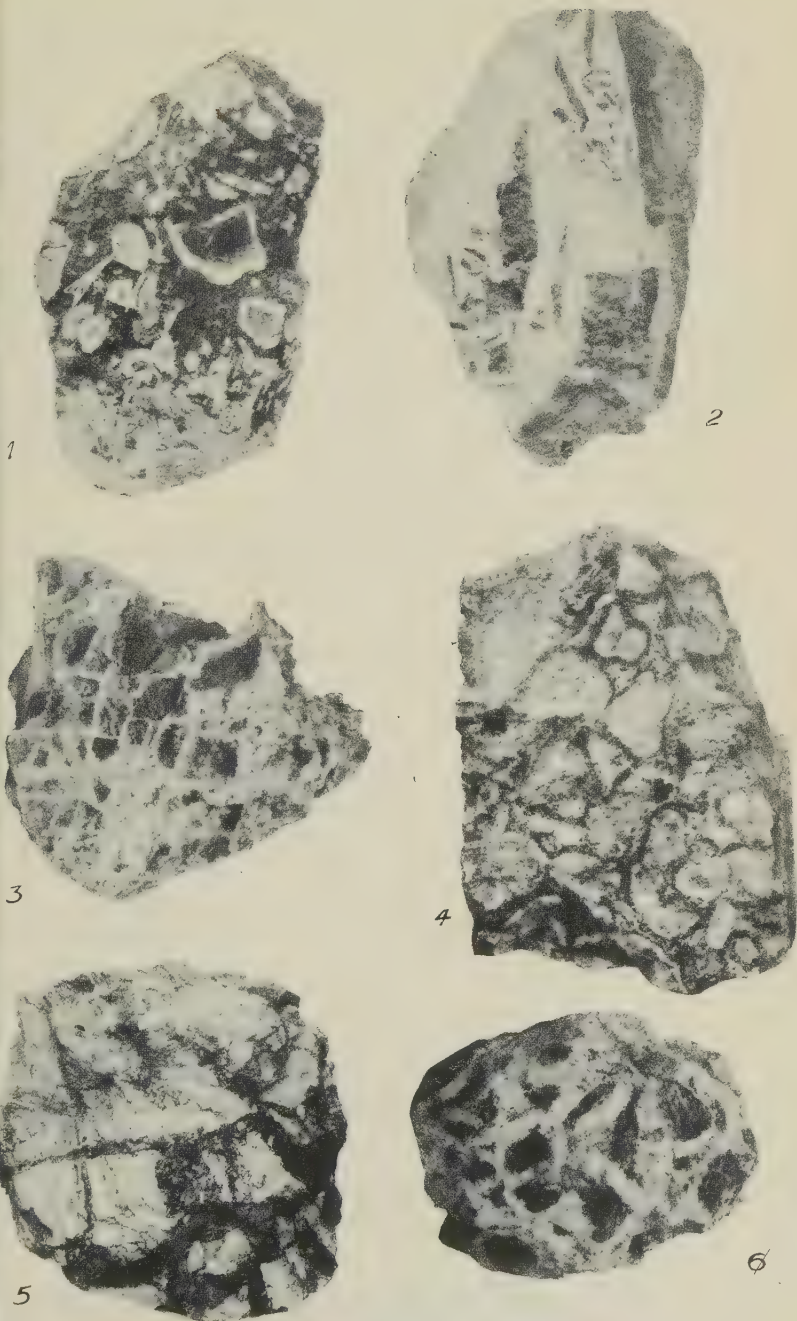
The supposition that unsupported fallen fragments and cleft and gaping masses of country-rock were kept in the positions in which they appear in breccias until the filling up of free spaces by secondary deposits is manifestly untenable.

Hydrostatic pressure regarded as a brecciating agent.—If we may accept the postulate that all spaces filled by the cementing materials of breccia were first occupied by solutions of the same, we have practically arrived at an explanation of the origin of those fissure-breccias whose structure, like that of some above described, gainsays the assumption that their fragmental inclusions were disrupted from country-rock or vein-stuff by earth-movements. The features of such breccias and of fissile rock-walls enclosing them are readily explicable as the results of the hydrostatic pressure and movement and usually also of the solvent properties of mineralizing waters flowing through deep fissures. Thus, while the deposition of cement-substance in rifts already formed was going on, the opening-out of fresh channels and the occasional quiet disruption of rock-fragments could be effected. Sorby¹ has shown that pressure may be an important factor in determining the solution of rock-constituents. Doubtless, too, its solvent action is greatly enhanced by high temperatures, which, moreover, by lessening the viscosity of water, promote its flow through capillary openings.²

It should, in addition, be noted that orogenic movements productive of new fissures, seasonal variations in the vadose or shallow underground circulation of water, surface denudation, and all other causes of relief of hydrostatic pressure would further brecciation by allowing of the

¹ H. C. Sorby, loc. cit., p. 224.

² C. R. Van Hise, 'A Treatise on Metamorphism,' Monogr. U. S. Geol. Surv., 1904, p. 1027.



F. H. BUTLER : BRECCIATION OF MINERAL-VEINS.

regurgitation of fluid with its suspended particles out of the saturated wall-rock into the cavities of veins.

Testimony to the existence of considerable hydrostatic pressure previous to the infilling of fissures is afforded by the splitting and bulging of bands of cleavable rock occurring in Cornish and many other vein-stones, e.g. in auriferous chloritic lode-stuff from Greenwood, British Columbia (fig. 20). The latter shows also the commencement of concretion of country-rock at the point of intrusion of quartz.

A specimen of jasper-breccia in the author's possession (fig. 21) evidences the fragmentation along cleavage-directions and the subsequent calcification of dark-coloured country-rock by the flow of a clear solution of quartz.

Other good examples of the fission of a soft rock by lode-waters are the quartz-chalcopyrite-killas-breccias of Fowey Consols and Wheal Tolgus, Cornwall (Nos. 295 and 250, Coll. Mus. Pract. Geol.).

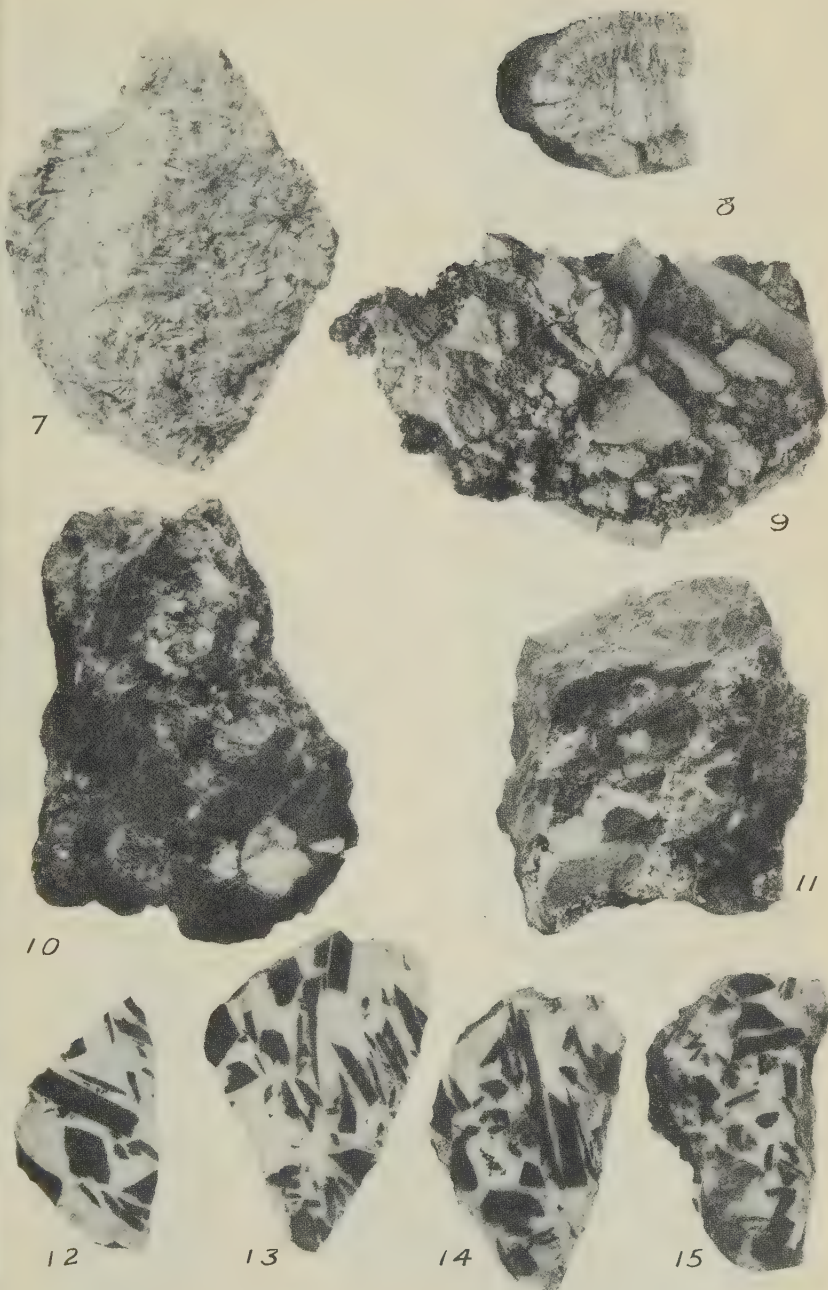
CONCLUSIONS.

Brecciated mineral-veins may be classed as those in which the material cemented is (1) rock fractured *in situ*; (2) fragments of the walls or of the contents of veins dislocated into fissures by regional disturbances; (3) similar fragments shifted from their original positions by the hydrostatic pressure and the solvent action of water flowing at great depths.

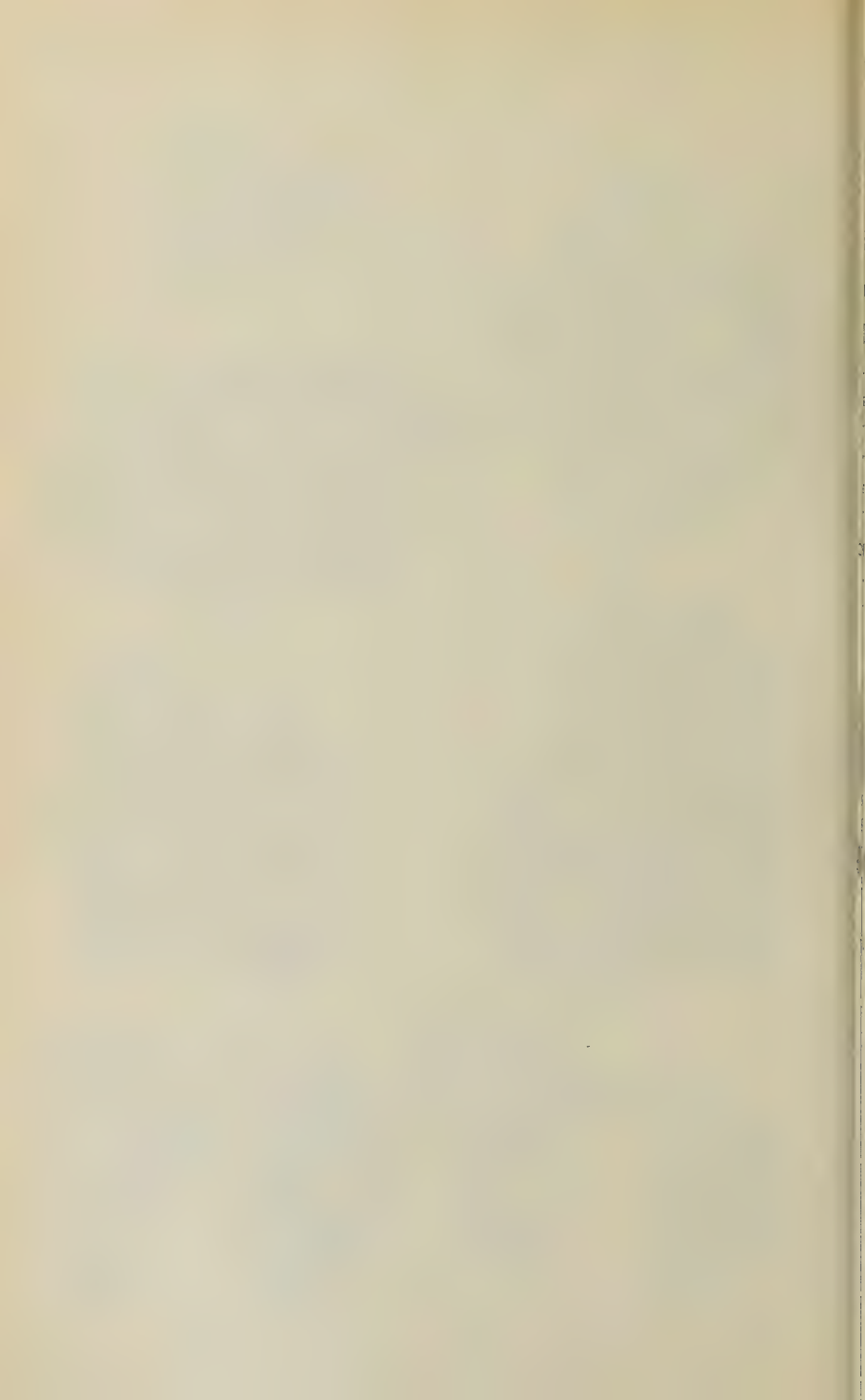
Owing to the variety of influences to which the contents of mineral-veins may be subjected, very careful consideration may be necessary in order to determine whether any particular brecciated portion should be referred to one or more of these three classes.

EXPLANATION OF PLATES IV-VI.

- Fig. 1. Vein-breccia from Esgair Hir mine, Cardiganshire (Coll. Mus. Pract. Geol., No. 374): actual size, 10×16.4 cm. (p. 125).
- „ 2. Vein-breccia from the Perran lode, near Marazion, Cornwall: actual size, 9.5×16.0 cm. (p. 125).
- „ 3. Breccia-like lode-material from Restormel mine, Lostwithiel, Cornwall: actual size, 8.0×11.5 cm. (p. 125).
- „ 4. Vein-breccia from Grassington lead-mines, Yorkshire (Coll. Mus. Pract. Geol., No. 346): actual size, 17.5×24.0 cm. (p. 127).
- „ 5. Vein-breccia from Cronebane mine, Co. Wicklow, Ireland (Coll. Mus. Pract. Geol., No. 347): actual size, 21.0×21.0 cm. (p. 127).
- „ 6. Vein-breccia from near Sourton, Devon: actual size, 8.5×11.2 cm. (p. 127).
- „ 7. Quartz-rock (an altered vein-breccia) from Wheal George, near Dittisham, Devon: actual size, 15.0×18.5 cm. (p. 127).
- „ 8. Quartz-rock in vein-stone similar to No. 7, from Peak Hill, near Dittisham, Devon: actual size, 4.0×4.5 cm. (p. 127).
- „ 9. Quartz-cuprite-fissure-breccia from Wheal Phoenix, Cornwall (Coll. Mus. Pract. Geol.): actual size, 17.4×27.4 cm. (p. 128).
- „ 10. Breccia-conglomerate from Relistian mine, Gwinear, Cornwall (Coll. Mus. Pract. Geol., No. 385): actual size, 22.0×29.0 cm. (p. 129).
- „ 11. Slate-chalybite-quartz-fissure-breccia from Allenheads, Northumberland (Coll. Mus. Pract. Geol., No. 378): actual size, 14.0×13.0 cm. (p. 130).
- „ 12. Lead-lode breccia from Wheal Betsy, Mary Tavy, Devon: actual size, 4.3×7.8 cm. (p. 130).
- „ 13. Lead-lode breccia from Wheal Betsy, Mary Tavy, Devon (section parallel to No. 12): actual size, 6.5×9.7 cm. (p. 130).
- „ 14. Lead-lode breccia from Wheal Betsy, Mary Tavy, Devon (section parallel to No. 13): actual size, 6.3×10.0 cm. (p. 130).
- „ 15. Lead-lode breccia from Wheal Betsy, Mary Tavy, Devon (section parallel to No. 14): actual size, 5.7×10.0 cm. (p. 130).
- „ 16. Slate-quartz-barytes-breccia from Pont Bren, Aberdaron, North Wales: actual size, 8.5×15.0 cm. (p. 131).
- „ 17. Lead-lode slate-quartz-galena-breccia from Pont Erwyd, North Wales: actual size, 7.0×9.8 cm. (p. 131).
- „ 18. Junction of vein-breccia and country-rock, Deyon United mine, Peter Tavy, Devon: actual size, 8.8×14.0 cm. (p. 132).
- „ 19. Slate-quartz-breccia from near Sourton, Devon: actual size, 8.5×11.9 cm. (p. 132).
- „ 20. Quartz-chlorite-killas-vein-breccia (transverse section), from Greenwood, British Columbia: actual size, 5.0×11.0 cm. (p. 135).
- „ 21. Green and white jasper-breccia, from India: actual size, 6.3×15.5 cm. (p. 135).



F. H. BUTLER: BRECCIATION OF MINERAL-VEINS.

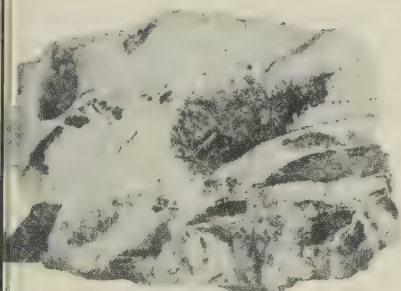




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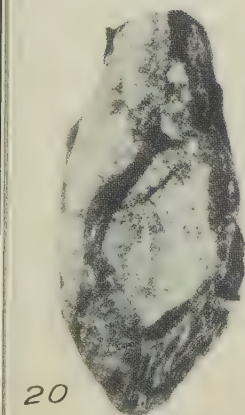
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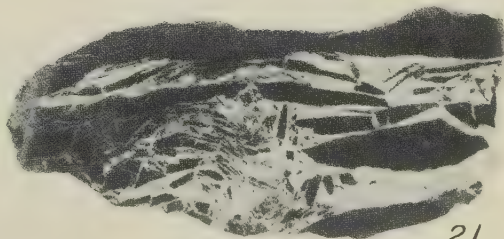
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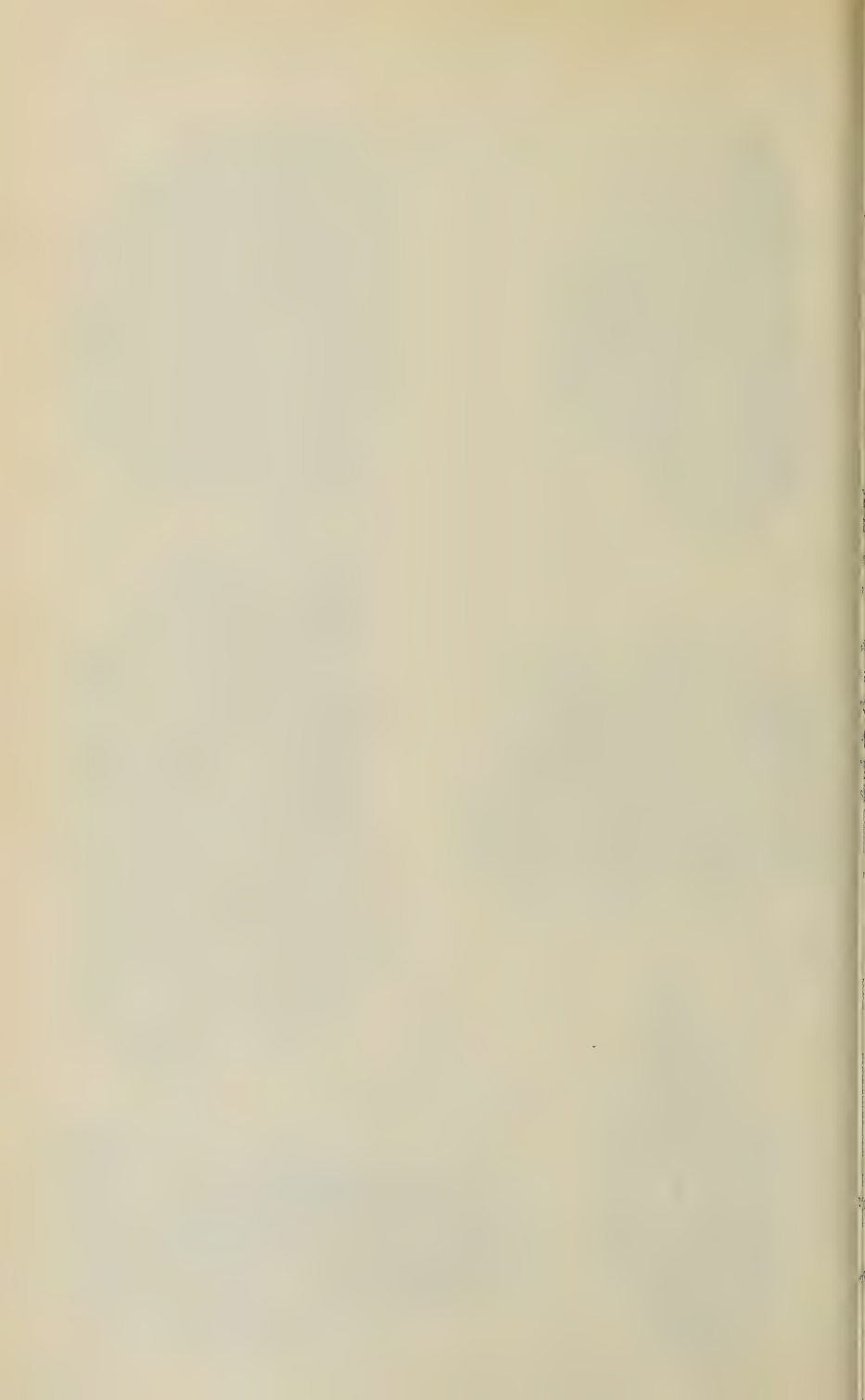
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21



Note on some artificially-produced crystals of Gypsum.

By the Rev. MARK FLETCHER, M.A., F.G.S.

Lecturer in Crystallography and Mineralogy, Armstrong College,
Newcastle-upon-Tyne; and Vicar of North Sunderland.

[Read June 13, 1911.]

PROFESSOR H. LOUIS, of Armstrong College, handed over to me for examination some crystals of gypsum which had been sent to him by Mr. Frank E. Lott, A.R.S.M., F.I.C., of Burton-on-Trent. Mr. Lott has kindly furnished me with the following particulars.

The crystals were deposited in an apparatus employed for raising steam in the production of distilled water. This apparatus consists of a copper vessel enclosing steel steam pipes for heating the water. The crystals were deposited on the walls of the copper vessel and on the steel pipes, and had been formed within a period of twelve months. The water used in the vessel was the typical Burton shallow-well water,¹ derived from the red gypseous marls of the Keuper-beds; it contained:—

	Parts per 100,000.			
Calcium sulphate	...	...	...	53.6
Calcium carbonate	...	...	...	19.0
Magnesium nitrate	...	...	...	19.9
Magnesium sulphate	...	...	...	18.7
Magnesium carbonate	...	...	...	1.9
Sodium sulphate	...	...	...	5.4
Potassium and sodium chlorides	...	...	...	14.7
Ferric oxide, alumina, silica, &c.	...	...	...	1.9
Total solids, dried at 180° C.				135.1

The specimens received consist of fairly large, distinctly-developed crystals standing out from a thin friable crust of more finely crystallized

¹ F. E. Lott and C. G. Matthews, 'The waters of Burton-on-Trent,' Journ. Soc. Chem. Industry, 1911, vol. xxx, pp. 69-70.

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Magnesium sulphate	...	...	...	...	18.7
Magnesium carbonate	...	...	...	...	1.9
Sodium sulphate	...	...	...	..	5.4
Potassium and sodium chlorides	...	...	...	...	14.7
Ferric oxide, alumina, silica, &c.	...	...	...	...	1.9
Total solids, dried at 180° C.					135.1

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¹ F. E. Lott and C. G. Matthews, 'The waters of Burton-on-Trent,' Journ. Soc. Chem. Industry, 1911, vol. xxx, pp. 69-70.

material. The crystals are transparent, and of a pale yellowish or creamy shade of colour, and they measure 1 to $1\frac{1}{2}$ cm. in length by about $\frac{1}{2}$ cm. in thickness. They are prismatic in habit, with a pyramidal termination of four striated faces, and they present quite the aspect of orthorhombic crystals. The crystals are freely developed at their upper ends, but at their lower ends they are somewhat intergrown, and this, together with a curvature of the faces, produces a tapering of the prismatic form.

A quantitative chemical analysis of the crystals, made by Mr. R. C. Burton, B.Sc., of this college, gave results agreeing with the gypsum formula $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$. No magnesium is present. The specific gravity is 2.32.

Although the crystals show no re-entrant angles, the presence of twinning is at once betrayed by the herring-bone striations on the face $b(010)$ parallel to the highly perfect cleavage. The nature of this twinning is evident when a cleavage-flake taken from a crystal is examined between crossed nicols. The two portions extinguish symmetrically with respect to the central dividing line or twin-suture, the angle of extinction being 15° on either side of this line. The twin-plane is therefore $d(101)$.

On the Fuess goniometer only approximate measurements could be obtained, since the faces give bands of reflected images. The following readings were taken for the brighter portions of the bands. The faces of the prism $m\{110\}$ are deeply striated parallel to their intersection with those of $b\{010\}$; and $g\{230\}$ is present only as striae on m . The faces of $l\{111\}$ are much rounded, and the angles for these are only approximate.

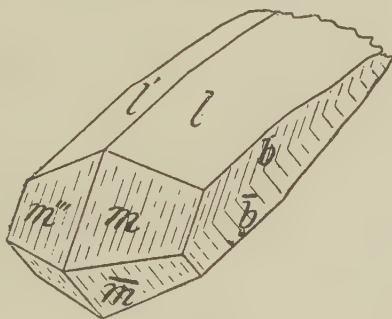
		Measured.		Calculated. ¹
$mm''' = (110) : (\bar{1}\bar{1}0)$	...	$68^\circ - 68\frac{1}{2}^\circ$	...	$68^\circ 30'$
$bg = (010) : (230)$	...	42 — 48	...	45 36
$ll' = (111) : (\bar{1}\bar{1}\bar{1})$	...	30 — 33	...	36 12
$m\bar{m} = (110) : (\bar{1}\bar{1}0)$	...	60 — $60\frac{1}{2}$	...	60 32

That the twin-plane is $d(101)$ is proved by the parallelism (or approximate parallelism allowing for the curvature of the l faces) of the twin-suture with the edges of the zone $[bl]$, and also by the measured angle $m\bar{m}$. This is the rarer of the two twin-laws of gypsum, by far the more common law being that with $a(100)$ as twin-plane. Further, in the d -twins it is usually the free end of the crystals that shows the re-entrant

¹ Dana's 'System of Mineralogy,' 6th edit., 1892.

angles between the m -faces, but in the crystals here described the salient angles of the twin are at the free end.

The thin base, to which the larger crystals above described are attached, consists of an aggregate of much smaller crystals of gypsum, about 2 mm. across, which are of quite a different habit. These have the form of thin lenticles with a large development of the basal plane $\{001\}$, $m\{110\}$ being small, and $b\{010\}$ apparently absent. These forms were determined under the microscope from the extinction-directions on the narrow cleavage-flakes. It is of interest to note that these smaller crystals are not twinned, whereas the larger crystals are invariably twinned as illustrated in the text-figure.



Twinned crystal of artificial Gypsum.

The formation of the smaller untwinned crystals of gypsum in the early stages of deposition and of the larger twinned crystals at a later stage, suggests that the production of the latter was influenced by the concentration of the solution, either of the calcium sulphate itself or of the associated salts. In this connexion it may be recalled that the artificial gypsum crystals recently described by Mr. C. J. Woodward¹ were also untwinned and in all probability deposited from a dilute solution, though under quite different conditions.

Of further interest is the presence of a later deposit of calcium carbonate on the larger twinned crystals of gypsum. This has the form of small cauliflower-like masses, which under the microscope are seen to consist of radial aggregates of minute needles a few hundredths of a millimetre in length. These were determined to be aragonite.

¹ C. J. Woodward, 'Note on gypsum crystals found lining a disused well at chemical works,' *Mineralogical Magazine*, 1907, vol. xiv, p. 211.

The larger Diamonds of South Africa.

By L. J. SPENCER, M.A., F.G.S.

Assistant in the Mineral Department of the British Museum.

[Read June 18, 1911.]

THE inquiry that I have recently made into the weight of the 'Cullinan' diamond¹ has led me to clear up, as far as possible, various discrepancies in the published statements respecting the other large diamonds of South Africa. Although a knowledge of the exact weights of these stones is a matter of only trivial scientific importance, yet it is desirable to place on record any definite facts that may still be gathered respecting them. Much valuable information in this direction has been freely given to me by Messrs. Wernher, Beit & Co., through whose hands several of the larger stones have passed; without their help the present notes could not have been written, and I therefore desire to express to them my hearty thanks.

THE 'EXCELSIOR' DIAMOND.

Next to the 'Cullinan', this is the largest of known diamonds. It was found on June 30, 1893, in the Jagersfontein diamond mine in Orange Free State. Pictures of this stone are given in several of the books on precious stones; and a glass model of it has been presented to the British Museum collection by Messrs. Wernher, Beit & Co. The various published statements of its weight range from 969 to 972 carats, that most frequently quoted being $971\frac{3}{4}$ carats. Messrs. Wernher, Beit & Co., in whose possession the stone, in its uncut form, remained for several years, inform me that the correct weight is $969\frac{1}{2}$ carats. They also kindly allowed me to compare against gram-weights the carat-weights² in use at their office, and their unit proved to be the English (Board of Trade) carat of 205.304 milligrams. The weight of the 'Excelsior' in the rough was therefore 199.04 grams.

¹ L. J. Spencer, 'Notes on the weight of the "Cullinan" diamond, and on the value of the carat-weight,' *Mineralogical Magazine*, 1910, vol. xv, pp. 318-326.

² Supplied by Messrs. De Grave, Short & Co., of Hatton Garden, London. Compare *Mineralogical Magazine*, 1910, vol. xv, p. 321.

The glass model, mentioned above, measures 5.86 by 5.47 cm. with a thickness of 2.4 to 3.1 cm. It is irregular and flattened in form with a curved outline, but at one end it is bounded by a large flat surface (3 by 4.8 cm.) representing a cleavage.

This stone has very often been confused with the 'Jubilee' diamond (p. 142), and most of the books state¹ that it was cut as a brilliant of 239 carats. This error has recently been corrected by Professor Max Bauer,² though the weights he mentions differ slightly from those now given.

Failing to find a purchaser, the stone was left intact until the year 1908, when it was cleaved and cut by Messrs. I. J. Asscher & Co., of Amsterdam, into a number of smaller brilliants, which were sold to various persons in London and America. The weights and descriptions of these twenty-one brilliants, as supplied to me by Messrs. Wernher, Beit & Co. and by Messrs. I. J. Asscher & Co., are as follows, together with the calculated weights in metric carats.

Brilliants cut from the 'Excelsior' Diamond.

No.		English carats.	Metric carats. ³	No.		English carats.	Metric carats. ³
1	Drop . .	67 $\frac{7}{8}$	69.68	11	Drop . .	9 $\frac{9}{16}$	9.82
2	" . .	45 $\frac{13}{16}$	47.08	12	" . .	3 $\frac{21}{32}$	3.75
3	" . .	45 $\frac{11}{16}$	46.90	13	Marquise	3 $\frac{1}{4}$	3.84
4	Marquise	39 $\frac{3}{16}$	40.23	14	Drop . .	2 $\frac{9}{32}$	2.84
5	Drop . .	34	34.91	15	Marquise	2 $\frac{1}{32}$	2.08
6	Marquise	27 $\frac{7}{8}$	28.61	16	Drop . .	1 $\frac{11}{32}$	1.87
7	"	25 $\frac{3}{8}$	26.30	17	" . .	1	1.03
8	"	23 $\frac{11}{16}$	24.31	18	Marquise	$\frac{3}{4}$	0.77
9	Drop . .	16 $\frac{11}{32}$	16.78	19	3 small brilliants	$\frac{5}{8}$	0.64
10	" . .	13 $\frac{1}{2}$	18.86				

The total weight of the twenty-one brilliants is 364 $\frac{3}{32}$ English carats or 373.75 metric carats (= 74.75 grams), corresponding to a yield from the rough stone of 37 $\frac{1}{2}$ per cent.

¹ This statement having been copied either directly or indirectly from Dr. G. F. Kunz's Report on Precious Stones for 1900 (Mineral Resources, United States Geol. Survey, 1901, p. 18 of the preprint, but not in the bound volume as issued).

² M. Bauer, 'Edelsteinkunde,' 2nd edit., 1909, pp. 320-321.

³ To convert the weights in metric carats to weights in grams, divide by 5.

THE 'JUBILEE' DIAMOND.

This is another of the large stones from the Jagersfontein diamond mine in Orange Free State. It was found at the end of the year 1895 and was at first known as the 'Reitz' diamond, in honour of the retiring president, F. W. Reitz, of the Orange Free State. After being cut in 1897, the year of the diamond jubilee of Queen Victoria, it was re-named the 'Jubilee'.

A plaster model of the uncut stone was lent by Messrs. Wernher, Beit & Co. for copies to be taken for the British Museum collection. This model has the form of a somewhat irregular and flattened octahedron (fig. 1), measuring $5.5 \times 4.8 \times 3.1$ centimetres; the large triangular face

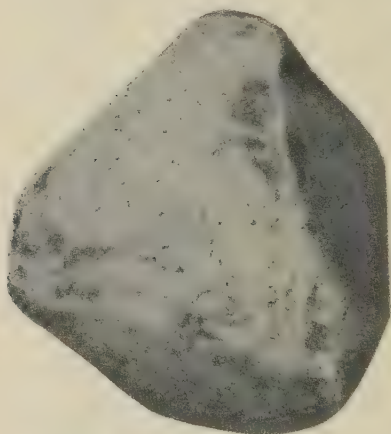


FIG. 1.—The 'Jubilee' diamond in its original form.

(Photograph¹ of plaster model : actual size.)

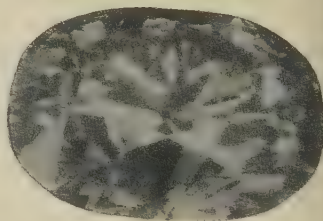


FIG. 2.—The 'Jubilee' diamond cut as a brilliant.

(Photograph of the actual stone : natural size.)

has an edge of 4 cm. Its volume is about 37 cubic centimetres, which would correspond with a weight of about 130 grams for the original stone.

The weight of the original stone was given to me by Messrs. Wernher, Beit & Co. as 634 carats.² As the stone was found subsequently to the

¹ For the photographs for figs. 1, 3, and 4. my thanks are due to Mr. Frank Stevens.

² The same weight, 634 carats, is given by L. de Launay, 'Les Diamants du Cap,' Paris, 1897, p. 61. Other accounts give 640 (G. F. Kunz, Annual Report on Precious Stones for 1895, 17th Ann. Rep. United States Geol. Survey, 1896,

date of the Board of Trade definition of the English carat in 1888 and 1889, we may assume that the carat is one of 205.304 milligrams. The weight of the original stone was therefore 130.16 grams or 650.8 metric carats.

According to information supplied by Messrs. Wernher, Beit & Co., this stone was cut in December 1896 to May 1897, producing a brilliant of 239 carats (= 49.07 grams) and a pendeloque brilliant of 13 carats. This brilliant of 239 carats is erroneously stated in many of the books on precious stones to have been cut from the 'Excelsior' diamond (p. 140). Its size¹ is $4.2 \times 3.55 \times 2.6$ cm. It still remains in the possession of Messrs. Wernher, Beit & Co., and a photograph (reproduced in fig. 2) of the actual brilliant was given to me by Mr. Alexander Knaus.

THE 'IMPERIAL' DIAMOND.

This stone, also known as the 'Victoria' or 'Great White' diamond, appeared surreptitiously on the London market in 1884, having presumably been stolen from the mines and smuggled from the Cape. In all probability it came from the Jagersfontein mine in Orange Free State. Its weight was stated to be 457 carats, and it was cleaved and cut by the late Jacques S. Metz at Amsterdam in 1885-6, yielding an oval brilliant of 180 carats and a smaller round brilliant of $19\frac{5}{8}$ carats. The large brilliant was sold to the Nizam of Hyderabad, and gave rise to a well-known lawsuit.

These particulars have been kindly given to me by Mr. James A. Forster, of Holborn Viaduct, London, who was one of the diamond merchants forming the syndicate for the purchase of the rough stone in 1884. He also obligingly lent me leaden models, made by himself at the time, of the uncut and cut stones, from which plaster copies have been taken for the British Museum collection.

The model of the uncut stone (fig. 3) is elongated and rounded, and much like a gherkin in shape. The only indication of any crystalline structure is the presence of a stepped cleavage surface at one end. The dimensions are $5.8 \times 3.35 \times 2.95$ cm., and the volume about 27 c.c. (corresponding to a weight of about 95 grams for the original stone). The model of the cut stone (fig. 4) shows an oval outline rather flattened

part iii, p. 898), and 655 carats (M. Bauer, 'Edelsteinkunde,' 1st edit., 1896, pp. 240, 243, and English translation by L. J. Spencer, 1904, pp. 208, 210, 254).

¹ A glass model of this brilliant, acquired in 1903 from a German dealer, measures $4.29 \times 3.68 \times 2.84$.

along one of the longer sides. It measures¹ $4.04 \times 3.24 \times 2.4$ cm., and has a volume of about 10 c.c. (corresponding to a weight of about 35.2 grams for the original brilliant).

Not knowing the value of the carat-weights against which these stones were weighed, it is impossible now to arrive at their exact weights. They can only be given approximately as 93.8 grams for the uncut and 36.9 grams for the cut stone.

The picture (fig. 3) here given of the uncut stone differs entirely from that given by Dr. G. F. Kunz,² and copied by Professor Max Bauer³ and

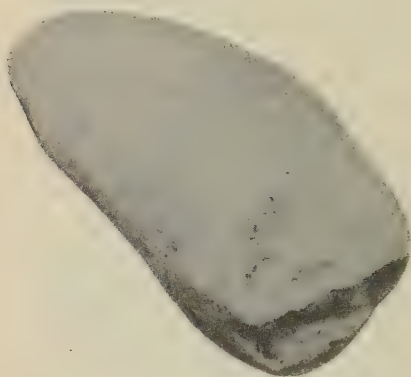


FIG. 3.—The 'Imperial' diamond in its original form.

(Photograph of plaster model : actual size.)

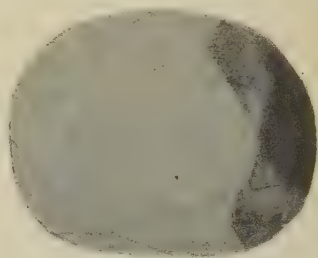


FIG. 4.—The 'Imperial' diamond cut as a brilliant.

(Photograph of plaster model : actual size.)

Professor R. Brauns.⁴ These represent the stone as a rounded octahedron, the weight of which is given as $457\frac{1}{2}$ carats. Dr. Kunz, after remarking that little is known of the history of this diamond, and quoting various conflicting accounts as to its origin, states that the figure he gives was

¹ G. F. Kunz (Science, New York, 1887, vol. x, p. 69) gives the dimensions as $3.95 \times 3.0 \times 2.3$ cm. A glass model supplied in 1910 by Dr. F. Krantz, of Bonn, measures $3.9 \times 3.14 \times 2.47$ cm. : it incorrectly shows the table facet too small, and the flattened side of the oval outline of the girdle is wanting.

² G. F. Kunz, 'Four large diamonds from South Africa,' Science, New York, 1887, vol. x, pp. 69-70.

³ M. Bauer, 'Edelsteinkunde,' 1st edit., 1896, p. 289; 2nd edit., 1909, p. 319; English translation ('Precious Stones') by L. J. Spencer, 1904, p. 253.

⁴ R. Brauns, 'Das Mineralreich,' 1903, p. 202; English translation ('The Mineral Kingdom') by L. J. Spencer, 1910, p. 207.

'drawn from two photos, that, strange to say, had been taken by a Cape photographer'. Now, as this diamond had been smuggled from the Cape, and was first openly offered for sale in London, there can be no evidence to connect Dr. Kunz's photographs with this particular stone. It is possible that they were of another stone, or enlarged photographs of a smaller diamond.

On pp. 146-147 are tabulated the main facts respecting four of the larger diamonds, which, with the expenditure of much time, I have been able to arrive at. In the same table are added particulars of other stones taken from the books on precious stones and other readily accessible sources in mineralogical literature. The latter have not been critically examined, and no doubt contain several inaccuracies. It is likely that in some of the earlier records the stones were weighed against the older English carat of 205.409 milligrams, which was in use at the time that the 'Koh-i-noor' was re-cut in England in 1852, and probably still later (compare foot-note 22, p. 147).

In addition to the diamonds mentioned in the table, many more large stones have within recent years been found in the Premier diamond mine, near Pretoria in the Transvaal. A list of the more valuable stones of over 100 carats, found between March, 1904 and April, 1911, has been kindly supplied to me by Mr. W. Busch, the manager of the London Diamond Office of the Premier (Transvaal) Diamond Mining Company, Ltd. This list of 58 items includes stones of $3,025\frac{3}{4}$ (the 'Cullinan'), 511, $487\frac{1}{4}$, $458\frac{3}{4}$, $391\frac{1}{2}$, 373, 348, and 334 carats, and ten others of over 200 carats each.

Mention may be here made of the fact that the 'Cullinan', although the largest crystal, is not the largest piece of diamond that has hitherto been discovered. A mass of carbonado weighing 3,078 carats (= 631.9 grams) was found in 1895 in Bahia, Brazil.¹

¹ J. R. Gregory, *Mining Journal*, 1895, vol. lxxv, p. 1536; J. K. Gulland, *Journ. Soc. Arts*, 1902, vol. li, p. 22, *Mining Journal*, 1909, vol. lxxxvii, p. 258; G. F. Kunz, *Mineral Resources, United States*, for 1902, 1904, p. 821, with fig.; J. Baszanger, *Mining Journal*, 1909, vol. lxxxvii, pp. 7, 333. Models of this piece of carbonado are supplied by Messrs. J. R. Gregory & Co., London.

No.	Name of Diamond.	Locality.	Date of find.	Weight in. roughly	
				English carats.	Grams
1	Cullinan . .	Premier mine, Transvaal .	25 January 1905 .	3025 $\frac{3}{4}$	621.20
2	Excelsior . .	Jagersfontein, O.F.S. . . .	30 June 1893 . .	969 $\frac{1}{2}$	199.04
3	Jubilee . .	Jagersfontein, O.F.S. . . .	End of 1895 . .	634	130.16
4	—	Jagersfontein, O.F.S. . . .	1883 or 1884 . .	over 600	—
5	—	Premier mine, Transvaal .	1905 or later . .	600	123.2
6	—	De Beers mine, Kimberley .	1 June 1896 . .	503 $\frac{1}{4}$	103.3
7	—	Kimberley mine, Kimberley	1892	474	97.3
8	Imperial . .	Cape	1884 or earlier .	457	93.8
9	De Beers . .	De Beers mine, Kimberley .	28 March 1888 .	428 $\frac{1}{2}$	88.0
10	—	De Beers mine, Kimberley .	Early workings .	409	84.0
11	—	Kimberley	Before 1896 . .	352 $\frac{3}{4}$	72.42
12	—	Jagersfontein, O.F.S. . . .	About 1906 . .	335	68.78
13	—	Premier mine, Transvaal .	13 February 1905	334	68.6
14	—	Vaal River	—	330 $\frac{1}{4}$	67.8
15	—	De Beers mine, Kimberley .	27 March 1884 .	302	62.0
16	Tiffany Yellow	Kimberley mine, Kimberley	About 1878 . .	—	—
17	Stewart . . .	Waldeck's Plant, Vaal River	1872	288 $\frac{3}{8}$	59.2
18	Du Toit I. . .	Dutoitspan mine, Kimberley	1878	244	50.1
19	Julius Pam. .	Jagersfontein, O.F.S. . . .	1889	241 $\frac{1}{2}$	49.6
20	Jagersfontein.	Jagersfontein, O.F.S. . . .	1881	209 $\frac{1}{4}$	43.0
21	Porter Rhodes	Kimberley mine, Kimberley	12 February 1880	149.6	30.71
22	Colenso . . .	[Kimberley], Cape	1883 or earlier .	129 $\frac{41}{64}$	26.62 $\frac{1}{2}$
23	Du Toit II. .	Dutoitspan mine, Kimberley	21 July 1871 . .	124	25.5
24	Tennant . . .	Cape	1873	112	23.0
25	Pam or				
26	Jagersfontein	Jagersfontein, O.F.S. . . .	Before July 1891	about 112	23
	Star of South Africa or Dudley . .	Orange River	March 1869 . .	83 $\frac{1}{2}$	17.15

¹ To convert grams to metric carats, multiply by 5.

- No. 4. E. W. Streeter, 'Precious Stones and Gems,' 4th edit., 1884, p. 98. (Very impure)
- „ 5. M. Bauer, 'Edelsteinkunde,' 2nd edit., 1909, pp. 258, 322. This is not included in the list of Premier stones supplied to me by Mr. W. Busch (p. 145); that, either this record is incorrect, or the stone was a low grade bort of little value.
- „ 6. Eighth Annual Report for the year ending 30 June 1896, De Beers Consolidated Mines, Ltd., p. 4. (A pale yellowish octahedron marred by a large number of black spots.)
- „ 7. M. Bauer, 'Edelsteinkunde,' 1896, p. 242, and later editions. (See note to No. 1.)
- „ 9. Second Annual Report for the year ending 31 March 1890, De Beers Consolidated Mines, Ltd., p. 20.
- „ 11. Information supplied by Mr. H. Hirsche, of Messrs. Wernher, Beit & Co., who showed me this beautiful yellow brilliant. It was cut in January 1896 as a brilliant of 207 $\frac{11}{16}$ carats and afterwards re-cut. Mr. Hirsche suggests that this stone may be identical with No. 7.

SOUTH AFRICA.

Number of cut stones.	Weight of cut stones.				Per- centage yield of cut material	Reference.
	Weight of largest.		Total weight.			
	English carats.	Grams. ¹	English carats.	Grams. ¹		
105	516 $\frac{1}{2}$	106.04	1036 $\frac{5}{32}$	212.73	34 $\frac{1}{4}$	Min. Mag., xv, p. 318.
21	67 $\frac{7}{8}$	13.94	364 $\frac{3}{32}$	74.75	37 $\frac{1}{2}$	This vol., p. 140.
2	239	49.07	252	51.74	39 $\frac{3}{4}$	This vol., p. 142.
—	—	—	—	—	—	E. W. Streeter, 1884. (4)
—	—	—	—	—	—	M. Bauer, 1909. (5)
—	—	—	—	—	—	(6)
1	200	41.1	—	—	42 $\frac{1}{4}$	M. Bauer, 1896. (7)
2	180	36.9	199 $\frac{5}{8}$	41.0	43 $\frac{3}{4}$	This vol., p. 143.
1	228 $\frac{1}{2}$	46.9	—	—	53 $\frac{1}{3}$	(9)
—	—	—	—	—	—	M. Bauer, 1909, p. 250.
1	199 $\frac{3}{32}$	41.02	—	—	56 $\frac{2}{3}$	(11)
47	40 $\frac{3}{64}$	8.40	138 $\frac{3}{64}$	28.34	41 $\frac{1}{4}$	(12)
—	—	—	—	—	—	M. Bauer, 1909, pp. 258, 322.
—	—	—	—	—	—	G. F. Williams, 1902. (14)
—	—	—	—	—	—	M. Bauer, 1896, p. 239.
—	125 $\frac{3}{8}$	25.7	—	—	—	G. F. Kunz, 1887. (16)
1	120	24.6	—	—	41 $\frac{1}{2}$	—
—	—	—	—	—	—	E. W. Streeter, 1882. (18)
1	120	24.6	—	—	50	(19)
—	—	—	—	—	—	E. W. Streeter, 1882, p. 95.
—	—	—	—	—	—	E. W. Streeter, 1882. (21)
—	—	—	—	—	—	(22)
—	—	—	—	—	—	E. W. Streeter, 1882, p. 190.
1	66	13.6	—	—	59	(24)
1	55	11.3	—	—	49	(25)
1	46 $\frac{1}{2}$	9.55	—	—	55 $\frac{2}{3}$	—

Information supplied by Mr. James A. Forster, who showed me models of the uncut stone and one of the larger drop brilliants. The stone was cut in 1910 in accordance with his instructions.

G. F. Williams, 'The Diamond Mines of South Africa,' 1902, p. 158.

G. F. Kunz, Science, New York, 1887, vol. x, p. 69.

E. W. Streeter, 'The Great Diamonds of the World,' 1882, p. 84.

Dana's 'System of Mineralogy,' 6th edit., 1892, p. 6; M. Bauer, 1896, p. 242.

Sir A. H. Church ('Precious Stones,' 1883, p. 47) gives the weight as 474 troy grains, and the specific gravity 3.523.

Presented to the British Museum collection by John Ruskin in 1887. The weight in carats here given is against the older English carat of 205.409 milligrams; if compared with the English (Board of Trade, 1888 and 1889) carat of 205.304 milligrams, the weight is $\frac{1}{16}$ carat more.

J. Tennant, Geol. Mag., 1875, dec. 2, vol. ii, p. 546, with 4 figs.; E. W. Streeter, 'The Great Diamonds of the World,' 1882, p. 215.

T. Reunert, 'Diamonds and Gold in South Africa,' 1893, p. 67. Possibly identical with the stone of 113 carats from Jagersfontein mentioned by E. Cohen (Neues Jahrb. Min., 1881, vol. i, p. 184).

In conclusion, I must confess that the present notes have been, in part at least, written with the object of pointing out once more, by means of concrete examples,¹ the absurdity of the present system of carat-weights. The use of the metric carat of 200 milligrams, a perfectly definite unit of weight, has recently been legalized in Bulgaria, Denmark, France, Holland, Japan, Norway, Portugal, Roumania, Spain, Sweden, and Switzerland; and the matter is receiving favourable consideration in Belgium, Italy, Mexico, Russia, and Servia.² It only remains for England and South Africa, Germany, and the United States to follow suit.

¹ A striking example is given by the case of the 'Florentine' or 'Austrian Yellow' diamond in Vienna, the weight of which had been variously stated to be $139\frac{1}{2}$ and $133\frac{1}{5}$ carats. Owing to this discrepancy the gem was weighed by Professor A. Schrauf in 1865 ('Gewichtsbestimmung, ausgeführt an dem grossen Diamanten des kais. österreich. Schatzes, genannt "Florentiner";' Sitzungsber. math.-naturwiss. Classe, Akad. Wiss. Wien, 1866, vol. liv, Abth. i, pp. 479-483) and found to be 27.454 grams, corresponding with $139\frac{1}{5}$ Florence carats, $133\frac{3}{5}$ Paris carats, and $133\frac{1}{5}$ Vienna carats. (The small differences in the fractions suggest that the Florence and Vienna carats have themselves not been always quite constant.)

² C. E. Guillaume, 'Les récents progrès du système métrique (deuxième suite),' Procès-verbaux des Séances du Comité international des Poids et Mesures, Paris, 1911, ser. 2, vol. vi, pp. 193-213. (See 'Nature,' 1911, vol. lxxxvii, p. 251.)

OBITUARIES.

MERVIN HERBERT NEVIL STORY-MASKELYNE (1823-1911).

(With Portrait, Plate VII.)

Nevil Story-Maskelyne¹ (or Maskelyne, as he was more often called) was born at Basset Down House, near Swindon, in Wiltshire, on September 3, 1823, and died at the same place on May 20, 1911. He was the son of Anthony Mervin Reeve Storey, F.R.S. (1791-1879), who in 1819 had married Margaret Maskelyne (1786-1858), the only child of the Rev. Dr. Nevil Maskelyne (1732-1811), the famous Astronomer-Royal. She was an accomplished woman, and the sole heiress of the Basset Down and Purton estates of the Maskelyne family in Wiltshire. Their son, Nevil Storey, entered Wadham College, Oxford, in 1840, where his father before him had had a distinguished career, and he took his degree in mathematics in 1845. Although originally destined for the legal profession (his father had practised as a barrister), he early took an interest in science, at a time when but few facilities were offered for its study in the University.

His early work was mainly in chemistry, which he studied with his friend, Benjamin Brodie. He also worked in Faraday's laboratory at the Royal Institution, and saw much of Liebig during the latter's visit to England. He played a prominent part in the establishment of science teaching in Oxford, and was secretary of the first committee formed to promote the scheme for building a university museum. From 1850 he acted as deputy reader in mineralogy in the place of Dean Buckland, and was appointed to the professorship² in 1856, a post held by him until 1895, when he was succeeded by H. A. Miers. Amongst those of his Oxford pupils are the well-known names, W. J. Lewis, L. Fletcher,

¹ Formerly Storey. In the titles of his published works his name appears variously as Storey Maskelyne, Nevil Story-Maskelyne, N. Story Maskelyne, N. S. Maskelyne, and Professor Maskelyne. His first name was often spelt Mervyn.

² The Oxford Chair of Mineralogy, founded in 1813, was officially styled a Readership, and in 1861 a Professorship.

and H. A. Miers. The duties of the professor were not very arduous, nor did they necessitate residence in Oxford for more than a short period each year. Under these circumstances he was able, whilst still holding the Oxford professorship, to accept the appointment of Keeper of Minerals in the British Museum, a post he held for nearly a quarter of a century (1857-80).

In 1857 the mineral collections of the British Museum were separated from the palaeontological collections, and a special department of minerals was created with Professor Story-Maskelyne as the first keeper. It was here that practically all his original work in mineralogy was performed, and he did much to raise the collection to its present high position amongst the mineral collections of the world. At first his only assistant was the late Thomas Davies, for whose training as a skilled mineralogist he was entirely responsible; later, at various periods, there were Dr. Viktor von Lang (1862-4), Dr. Walter Flight (1867-85), W. J. Lewis (1875-7), and L. Fletcher (1878-80). A chemical laboratory, so essential for the determination of minerals, was not placed at the disposal of the department until 1867, when one was fitted up in a private house outside the museum premises. Previous to that date, owing to fire risks, none but the very simplest chemical tests could be made, and this deficiency led to the development of optical and goniometrical methods. As early as 1861 a microscope fitted with a graduated rotating stage and accessories for polarized light was constructed for the examination of thin sections of meteoric stones; and a reflecting goniometer with telescope was designed for measuring crystals. In this way a considerable amount of important research work was performed; but in the meantime routine work connected with the registering, labelling, and arranging of the collections was not neglected. With the sole help of Thomas Davies large numbers of specimens which had been previously stored away were sorted and labelled, and the enormous mass of material in the whole collection was re-classified according to the crystallo-chemical system published by Gustav Rose in 1852.

During Story-Maskelyne's term of office the collections grew by the addition of no less than 43,000 specimens, many of them being selected individually on their own merits. For example, to mention only two specimens acquired respectively in 1858 and 1879: the 'Latrobe' nugget of crystallized gold weighing 23 oz. troy, from Victoria; and a large crystalline mass of bismuth with films of gold, from Bolivia. Mention may also be made of the Allan-Greg and the Koksharov collections acquired in 1860 and 1865 respectively, and the crystal collection

of Dr. A. Krantz in 1859. Special attention was given to the collection of meteorites, and the number of representative falls was increased from 72 to 312. All this work was done while the collections were still in the old British Museum building at Bloomsbury, before their removal to the Natural History Museum at South Kensington.

On the death of his father in 1879, the care of the family estates in Wiltshire and important public duties necessitated Story-Maskelyne's retirement from the British Museum in 1880, though he still held the Oxford professorship for many years later. For thirteen years (1880-92) he was a Member of Parliament for the Northern or Cricklade division of Wiltshire, and for a long period a member of the Wiltshire County Council and Chairman of its Agricultural Committee. He was also a county magistrate for Wiltshire and deputy-lieutenant for Brecknockshire. Although living the life of a country gentleman, interested in his estates and in the improvement of agriculture, he did not sever his connexion with the scientific world. For several years (1891-8) he was President of the Mineralogical Society, attending and presiding over its meetings with unfailing regularity, and with his fund of reminiscences adding much to the discussions. He was also Vice-President of the Chemical Society (1878-81), the Geological Society (1882-3), and the Royal Society (1897-9), and President of the Wiltshire Archaeological and Natural History Society (1883-6). He was a member (1881-94) of the British Association Committee on the teaching of science in elementary schools, and Chairman (1898-1903) of that on the structure of crystals.

Of his published works, special mention may be made of the catalogue of the Duke of Marlborough's collection of engraved gems (1870), and the treatise on crystallography published in 1895. Much of the latter had been written thirty years previously, and some of the proof-sheets had long been placed in the hands of students. Had its publication not been so long delayed many of the special descriptive terms that were proposed would, no doubt, have found acceptance by crystallographers. In his book, as in his lectures at Oxford and before the Chemical Society in 1874-5, he laid special stress on the symmetry of crystals.

In the determination of the mineral constituents of meteoric stones he did pioneer work, and was the first to recognize the presence of enstatite, whilst asmanite, oldhamite, and osbornite were described as new meteoric minerals. Cornish minerals also claimed his attention, and of these he long ago described and named andrewsite, langite, liskeardite, lyellite, and waringtonite, the first three of which still rank as well-defined

species. The wide interests he took may be judged from the accompanying bibliography. He gave much attention to the minerals that were used in classical times, and formed a fine collection of antique engraved gems.

The value of Story-Maskelyne's scientific work was recognized by the honours bestowed upon him from several quarters. In 1870 he was elected a Fellow of the Royal Society, of which his father and grandfather had also been Fellows. He was an Honorary Fellow of Wadham College, and in 1903 received the honorary degree of Doctor of Science at Oxford. Several foreign scientific societies elected him a corresponding member, and in 1893 he was awarded the Wollaston gold medal of the Geological Society.

He married in 1858 Thereza, daughter of J. Dillwyn Llewelyn, F.R.S.; she survives him, together with their three daughters, one the widow of the Rt. Hon. H. O. Arnold-Forster, and another the wife of Sir Arthur Rücker.

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¹ Compiled by G. Savigar, Chief attendant in charge of the Library of the Mineral Department, British Museum.

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- 1864 (20) New British mineral [langite]. *Phil. Mag.*, ser. 4, vol. xxvii, p. 316.
- (21) New minerals [waringtonite and lyellite] from Cornwall. *Chem. News*, vol. x, p. 263.
- 1865 (22) A theory of salts : a treatise on the constitution of bipolar (two-membered) chemical compounds. By C. B. Mansfield. [Edited by N. S.-M.] 8vo. London, 1865.
- (23) On new Cornish minerals of the brochantite group. *Proc. Roy. Soc.*, vol. xiv, pp. 86-89, 392-400; *Phil. Mag.*, ser. 4, vol. xxix, pp. 473-476.
- (24) On crystals of melaconite, and on tenorite. *Rept. Brit. Assoc.*, 1866, vol. xxxv (sect. 2), pp. 33-34.
- (25) The collections of the British Museum. Being a reprint, with a few additions and emendations, of two articles from 'The Times' of October 6 and 7, 1863. [By N. S.-M.] 8vo. pp. 69. London, 1865. Another reprint is dated 1867.
- 1865-66 (26) New Cornish minerals. *Chem. News*, vol. xii, p. 277; vol. xiii, pp. 10-11, 84.

- 1866 (24a) Ueber die Krystallgestalt des Kupferoxydes. *Verhandl. russ.-kais. mineralog. Gesellsch. St. Petersburg*, ser. 2, vol. i, pp. 147-150.
- 1868 (27) Report on jewellery and precious stones. *Reports on the Paris Universal Exhibition, 1867. London, 1868*, vol. ii, pp. 593-620.
- 1869 (28) On the chemical composition of Canaüba wax. *Journ. Chem. Soc.*, vol. vii (xxii), pp. 87-99.
- (29) On the nature and composition of the murrhine vases of the ancients, by H. M. Westropp: with observations by N. S. Maskelyne. *Proc. Soc. Antiq.*, ser. 2, vol. iv, pp. 222-224.
- (30) Preliminary notice on the mineral constituents of the Breitenbach meteorite. *Proc. Roy. Soc.*, vol. xvii, pp. 370-372; *Chem. News*, vol. xix, p. 182.
- (31) Dana's Mineralogy. [Review of the 5th edition.] *Nature*, vol. i, pp. 161-163, 186-187.
- 1870 (32) On the method of analysing silicates that do not gelatinise with hydrogen chloride. *Chem. News*, vol. xxi, pp. 27-28.
- (33) Whence come meteorites? *Nature*, vol. ii, pp. 77-78.
- (34) The Marlborough gems, being a collection of works in cameo and intaglio, formed by George, third Duke of Marlborough. Catalogued with descriptions, and an introduction. 4to. pp. xl + 118. Privately printed. [London,] 1870.
- (The introduction and abridgements of the catalogue were reprinted in the *Sale Catalogues of 1875 and 1899.*)
- 1870-71 (35) On the mineral constituents of meteorites. [2 parts.] *Proc. Roy. Soc.*, vol. xviii, pp. 146-157; vol. xix, pp. 266-268; *Phil. Trans.*, vol. clx, pp. 189-214, pls. 22, 23; vol. clxi, pp. 359-367.
- 1871 (36) (With W. Flight.) Mineralogical notices. 1. On the formation of basic cupric sulphates. 2. Opal, Waddela Plain, Abyssinia. 3. Francolite, Cornwall. 4. Epidote and Serpentine, Iona. 5. Vivianite. 6. Cronstedtite. 7. Pholerite. *Journ. Chem. Soc.*, vol. ix (xxiv), pp. 1-13.
- (37) Localities of diopside. *Rept. Brit. Assoc.*, 1872, vol. xli (sect. 2), pp. 74-75; *Chem. News*, vol. xxiv, p. 99.
- (38) On andrewsite. *Rept. Brit. Assoc.*, 1872, vol. xli (sect. 2), pp. 75-76; *Chem. News*, vol. xxiv, p. 99.
- 1872 (39) On meteoric stones. *Proc. Roy. Inst.*, vol. vi, pp. 513-517; *Chem. News*, vol. xxvi, pp. 61-62; *Pharmac. Journ.*, 1873, vol. iii, pp. 124-126.
- (40) On the mineral constituents of the Breitenbach meteorite. *Nature*, vol. vi, pp. 71-72.
- (41) (With W. Flight.) Mineralogical notices. 8. Isopyre. 9. Percylite. 10. Vanadinite. 11. Uranite. 12. Analyses of some pisolitic iron ores from North Wales. 13. Prasine. *Journ. Chem. Soc.*, vol. x (xxv), pp. 1049-1057.
- 1874 (42) (With W. Flight.) Mineralogical notices. 14. Caledonite. 15. Lanarkite. *Journ. Chem. Soc.*, vol. xii (xxvii), pp. 101-103.
- (43) (With W. Flight.) On the character of the diamantiferous rock of South Africa. *Quart. Journ. Geol. Soc.*, vol. xxx, pp. 406-416.
- (44) Doubtful minerals. *Chem. News*, vol. xxx, pp. 250-251.
- (45) [Some notes bearing on the symmetrical distributions of physical characters in crystals. 8vo pamphlet, pp. 20.]

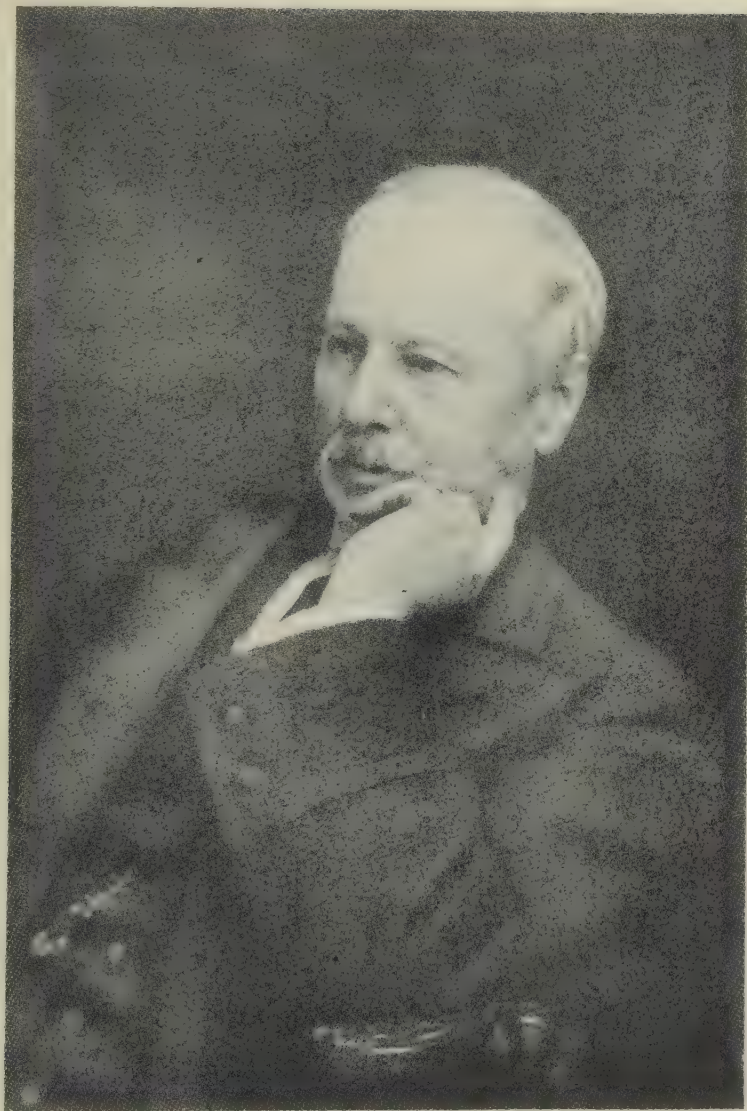
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- (48) Some lecture notes upon meteorites. *Nature*, vol. xii, pp. 485-487, 504-507, 520-523.
- (49) Instructions for making observations on, and collecting mineralogical specimens. (Forming pp. 77-82 of the *Manual of the Natural History, Geology, and Physics of Greenland and the neighbouring Regions* . . . Edited by Prof. T. Rupert Jones.) 8vo. London, 1875.
- (50) Lectures on the morphology of crystals, at the Chemical Society. *Chem. News*, vol. xxxi, pp. 3-4, 13-15, 24-26, 63-64, 101-103, 111-112, 121, 153-155, 200-202, 232. [Lectures I-XIV.] Reprint, London, 1875, 8vo, 47 pp.; *Nature*, vol. xi, pp. 187-190.
- 1876 (51) The Rowton siderite. *Nature*, vol. xiv, p. 272.
- (52) The pitted surface of meteorites. *Phil. Mag.*, ser. 5, vol. ii, pp. 126-131.
- (53) Crystallography—Mineralogy. Handbook to the special loan collection of scientific apparatus, 1876, South Kensington Museum, pp. 304-320.
- (54) [Discussion on crystallographic nomenclature.] Conferences held in connection with the special loan collection of scientific apparatus, 1876, South Kensington Museum, pp. 436-440.
- (55) The diamond fields of Griqualand and their probable influence on the native races of South Africa. *Journ. Soc. Arts*, vol. xxv, pp. 372-381.
- 1877 (56) On ludlamite, a new Cornish mineral, by F. Field [with crystallographic notice by Prof. Maskelyne]. *Phil. Mag.*, ser. 5, vol. iii, pp. 52-57; *Proc. Crystallog. Soc.*, 1877, Pt. 1, pp. 26-31.
- (57) Note on the optical characters of ludlamite. *Phil. Mag.*, ser. 5, vol. iii, pp. 135-137; *Zeits. Kryst. Min.*, vol. i, pp. 68-69.
- (58) Additional note on ludlamite. *Phil. Mag.*, ser. 5, vol. iii, p. 525.
- (59) On the discrimination of crystals by their optical characters. [Lecture before the Chemical Society, on April 5, 1877.] *Chem. News*, vol. xxxv, pp. 152-154.
- (60) (With W. J. Russell.) An attempt to form double salts of nitrate of silver and other nitrates. *Proc. Roy. Soc.*, vol. xxvi, pp. 357-359.
- (61) Indium in British biendes. *Nature*, vol. xvii, p. 5.
- (62) Stonehenge: the petrology of its stones. *Wiltshire Arch. Nat. Hist. Mag.*, vol. xvii, pp. 147-160, with 1 plate. [Also as a privately printed pamphlet, pp. 5, Salisbury, 1876: The petrology of the Stonehenge stones.]
- (63) Ueber Quarz-Krystalle mit der Basis. *Zeits. Kryst. Min.*, vol. i, p. 67.
- (64) Troy, Mycenae, and Dr. Schliemann. *Wiltshire Times*, April 5, 1877.
- 1878 (65) A new mineral [liskeardite]. *Nature*, vol. xviii, p. 426.
- 1879 (66) Petrology. [Transit of Venus Expedition, 1874-75.—Collections from Rodriguez.] *Phil. Trans.*, vol. clxviii, pp. 296-301.
- (67) Crystallography of the nitrosoterpene of Dr. Tilden. *Phil. Mag.*, ser. 5, vol. vii, pp. 129-133; *Proc. Crystallog. Soc.*, 1882, pt. 2, pp. 54-58, pl. 4.
- (68) On an artificial diopside rock formed in a Bessemer converter by Mr. Percy Gilchrist. *Phil. Mag.*, ser. 5, vol. vii, pp. 133-134; *Proc. Crystallog. Soc.*, 1882, pt. 2, pp. 59-60.

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- 1880 (70) The asserted artificial production of the diamond. *Nature*, vol. xxi, pp. 203-204.
The supposed artificial production of the diamond. *Chem. News*, vol. xli, pp. 4-5.
- (71) Artificial diamonds. *Nature*, vol. xxi, p. 260; *Journ. Soc. Arts*, vol. xxviii, p. 289. (From 'The Times'.)
- (72) [Obituary notice of] Prof. W. H. Miller. *Chem. News*, vol. xli, pp. 97-98.
- (72) [Obituary notice of] Prof. W. H. Miller. *Nature*, vol. xxii, pp. 247-249.
- 1884 (73) President's Inaugural Address [on flints]. *Wilts. Arch. Nat. Hist. Mag.*, vol. xxi, pp. 274-286.
- 1885 (74) President's Address. *Wilts. Arch. Nat. Hist. Mag.*, vol. xxii, pp. 136-139.
- 1886 (75) Barbury Castle. *Wilts. Arch. Nat. Hist. Mag.*, vol. xxiii, pp. 180-194: 2 pls.
- 1891 (76) The Koh-i-Nur—a criticism. *Nature*, vol. xlv, pp. 555-559; vol. xlv, pp. 5-7.
- 1894 (77) Greek Art. (Lecture, reprinted from the *North Wilts. Herald*, March 16, 1894.) 4to pamphlet, pp. 2.
- 1895 (78) Crystallography: a treatise on the morphology of Crystals. pp. xii + 521, with 398 text-figs. and 8 pls. 8vo. Oxford, 1895.
- (79) An introduction to chemical crystallography. By A. Fock. Translated and edited by W. J. Pope, with a preface (pp. vii-xii) by N. Story-Maskelyne. 8vo. Oxford, 1895.
- 1896¹ (80) Mineral veins and their history. (Read October 17, 1895, before the Junior Engineering Society, G.W.R. Mechanics' Institution, New Swindon.) 8vo pamphlet, pp. 18, with 1 plate.
- 1898 (81) The place-name Cricklade: a suggestion. *Wilts. Arch. Nat. Hist. Mag.*, vol. xxx, pp. 95-99.
- 1907 (82) A glossary of terms relating to the making of butter, with explanations of such terms and simple discussions on principles involved in them. For the use of students in the Wilts. itinerant butter school. 4to. pp. 2+130, Trowbridge.
- N.D. (83) The metals and minerals of the Bible. 15 pp. (Printed by Eyre & Spottiswoode, London, [1888?].) (An abridgement appeared in the Variorum Teacher's Edition of the Holy Bible, London, 1898.)

CHARLES BARET (1831-1910).

Ch. Baret was born at Dinan in Brittany, and for thirty-seven years he carried on the business of apothecary in Nantes. His spare time was devoted to the collecting of minerals and in making a systematic mineralogical exploration of the department Loire-Inférieure. He was an original member of the French Mineralogical Society and three times its vice-

¹ The titles of this and of some of the other pamphlets have been taken from the Bibliography given in the *Wilts. Arch. Nat. Hist. Mag.*, 1911.



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M. H. NEVIL STORY-MASKELYNE (1823-1911).

(From a photograph taken in April, 1898.)

president, and several of his notes on the minerals of Loire-Inférieure were published in the Bulletin of the Society. Other publications were 'Description des Minéraux de la Loire-Inférieure' (1885),¹ 'Le pays de Guérande : Minéralogie' (1903), 'Catalogue de la Collection de Minéralogie de la Loire-Inférieure' (1905). The mineral bertrandite, first found in the neighbourhood of Nantes, was discovered by him, and first described by É. Bertrand. His collection of local minerals he gave to the museum at Nantes, and his general collection to the museum at Rennes. In an obituary notice (Bull. Soc. franç. Min., 1910, vol. xxxiii, pp. 295-296) Professor A. Lacroix acknowledges the assistance he received from Baret when writing his 'Minéralogie de la France'.

WILLIAM PHIPPS BLAKE (1826-1910).

After graduating in 1852 at the Sheffield Scientific School of Yale University, Professor W. P. Blake undertook at various times the duties of works-chemist, geologist on explorations and railroad surveys, mining engineer, editor of the 'Mining Magazine', commissioner to the Paris, Vienna, and other exhibitions, &c. In 1861-3 he acted as mining engineer to the Japanese Government, and he was one of the first teachers of science in Japan. In 1864 he was appointed Professor of Mineralogy and Geology in the College of California, and in 1895 Professor of Geology and Mining and Director of the School of Mines in the University of Arizona at Tucson, from which post he retired in 1905. He was also State Mineralogist and Geologist of Arizona. He was the author of numerous reports and papers, many of the latter, published in the 'American Journal of Science', being on mineral occurrences in the western states. The Royal Society catalogue of scientific papers gives, between 1850 and 1883, sixty-eight titles under his name. The now well-known name clinocllore was given by him so long ago as 1851.

Biographical notices, together with portrait and bibliography, are given by R. W. Raymond (Trans. Amer. Inst. Mining Engin., 1911, vol. xli (1910), pp. 851-864; Bull. Geol. Soc. Amer., 1911, vol. xxii, pp. 36-47).

SAMUEL FRANKLIN EMMONS (1841-1911).

After graduating at Harvard University in 1861, Dr. S. F. Emmons studied at the Paris School of Mines (1862-4) and the Freiberg Mining Academy (1864-5). This training well fitted him for the important

¹ A second edition with the title 'Minéralogie de la Loire-Inférieure' appeared in Bull. Soc. Sci. Nat. de l'ouest de la France, Nantes, 1898, vol. viii, pp. 1-175, with 19 plates.

work which he subsequently did on the Geological Exploration of the Fortieth Parallel (1867-77), and, since 1879, on the United States Geological Survey. His work on economic geology and ore-deposits is well known, and his elaborate monograph on the Leadville district in Colorado, published in 1883-6, still remains a pattern for the methodical examination and description of an ore-bearing district.

FELIX FRANZ XAVER KREUTZ (1844-1910).

Dr. Felix Kreutz was born at Neu-Sandee in Galicia on November 19, 1844, and after studying at Lemberg, Cracow, and Vienna, was attached during 1867-8 to the Austrian Geological Survey. He was successively Professor of Mineralogy in the High School and the University at Lemberg, and the Jagellonian University at Cracow. From the last post he retired in 1903, his successor being Professor J. Morozewicz, to whom his son, Dr. Stefan Kreutz, is now an assistant. He was a member of the Polish Academy of Sciences, and for a time director of its mathematical and natural sciences section.

Dr. F. Kreutz was the author of several geological, petrographical, and mineralogical papers. Of the latter may be mentioned his work on the colour, fluorescence, and phosphorescence of rock-salt and fluor-spar, and their alteration under the influence of the cathode rays, sodium vapour, and changes of temperature.

Obituary notices by R. Zuber and J. Morozewicz are given (in Polish) in 'Kosmos' (Lemberg), 1910, vol. xxxv, pp. 883 and 888, with portrait.

OTTO PAUL LUEDECKE (1851-1910).

Since 1884 Dr. Otto Luedecke was Extraordinary Professor of Mineralogy in the University of Halle. He was previously (from 1874) assistant in the Mineralogical Institute, and since 1899 its director. He was the author of numerous papers on the crystallography of various minerals and organic compounds, most of which were published in the 'Zeitschrift für Naturwissenschaften', a journal edited by him from 1882 to 1892. He paid special attention to the minerals of the Harz, Thuringia, and the Prussian salt-deposits, and his excellent volume 'Die Minerale des Harzes' (1896) will long remain a standard work of reference. His successor at Halle is Dr. H. E. Boeke. (See J. Walther, 'Leopoldina,' 1911, vol. xlvii, p. 16.)

WILLIAM FREDERICK PETTERD (1849-1910).

Mr. W. F. Petterd was a shoemaker by trade, and the possessor of a very flourishing business in Tasmania. He was a native of Hobart, but for many years had lived at Launceston. As an amateur he seems to have always been interested in scientific pursuits and a keen collector of objects of various kinds. He was well known to conchologists, and as long ago as 1879 wrote a monograph on the land shells of Tasmania. Through making assays for prospectors he came into touch with the newly developed mining districts of Tasmania, and in some of these he had substantial interests. This naturally led him to the collecting of minerals, and the enthusiasm with which he worked at this is well shown by his 'Catalogue of the Minerals of Tasmania', reprinted from the 'Papers and Proceedings of the Royal Society of Tasmania'. By the constant addition of new localities and species of Tasmanian minerals this catalogue grew from 72 pages in the first edition of 1893 to 221 pages in the third edition of 1910; and the number of recognized Tasmanian species and varieties was increased to 356. In addition, he described several new species, some of them perhaps on rather slender evidence, but one—*dundasite*—has since been recorded from three localities in the British Isles. His valuable collection of minerals he bequeathed to the Royal Society of Tasmania, and it is now deposited in the Tasmanian Museum at Hobart.

EMIL PHILIPPI (1871-1910).

Dr. E. Philippi was born at Breslau on December 4, 1871, and died at Assuan on February 26, 1910. For a short time he was an assistant in the geological department of the Berlin Museum, and in 1907 was appointed Extraordinary Professor of Geology and Palaeontology in the University of Jena. He had, however, travelled extensively, and as geologist took part in the German Antarctic Expedition of 1901-3. Although most of his papers were on geology and palaeontology, a few related to minerals, the most important being on the origin of dolomite, published in 1899 and 1907. (*See Geographen-Kalender, 1911, p. 270.*)

JAKOB MAARTEN VAN BEMMELEN (1830-1911).

After a chemical training, J. M. van Bemmelen became in 1856 a teacher in the agricultural school at Groningen. This led him to his life's work on the study of soils, which he attacked from the point of view of colloidal chemistry. From 1874 to 1900 he was Professor of

Inorganic Chemistry in the University of Leiden. Many of the results of his work on colloids are only now being appreciated by chemists and mineralogists. He also discussed the accumulation of iron and the origin of chalybite and vivianite in peat-bogs; and quite recently, at the age of eighty, he gave (*Zeits. Anorg. Chem.*, 1910, vol. lxvi, pp. 322-357) a detailed account of the various modes of weathering of silicate-rocks. (*See* H. E. Boeke, *Centralblatt Min.*, 1911, pp. 225-226.)

JACOBUS HENRICUS VAN 'T HOFF (1852-1911).

The celebrated Dutch chemist, J. H. van 't Hoff, was in 1878 appointed Professor of Chemistry, Mineralogy, and Geology in the University of Amsterdam, a post held by him until his call to Berlin in 1896, as director of a research laboratory under the Prussian Academy of Sciences and as Honorary Professor of Physical Chemistry in the University. It was since he went to Berlin that he applied himself and directed his pupils in the systematic study of the formation of oceanic salt-deposits, with special reference to those of the Stassfurt area. The important results of this work were given in a series of fifty-two papers between the years 1897 and 1908, and a collected account has been published under the title '*Zur Bildung der ozeanischen Salzablagerungen*' (2 parts, 1905 and 1909). The problem dealt with the equilibrium between different salts present in solution, and the determination of the limits of stability of the various double salts. A large number of minerals were so prepared artificially, and a new species (vanthoffite) discovered, but unfortunately the accounts of the experiments were unaccompanied by crystallographic descriptions of the materials obtained.

HENRY WURTZ (1828-1910).

Dr. Henry Wurtz was a contemporary of W. P. Blake (see above, p. 157) at the Sheffield Scientific School of Yale University, where in 1851 he was teacher of chemistry. The mineral wurtzilite was named after him by Blake. In 1853 he was chemist and mineralogist on the New Jersey Geological Survey, and in 1858 Professor of Chemistry in the National Medical College at Washington. The minerals animikite, grahamite, huntelite, and melanolite were described by him.

REVIEWS.

Handbuch der Mineralchemie. Herausgegeben von C. DOELTER. Vol. i, part 1, pp. 1-160, with 14 text-figures. (Dresden: Theodor Steinkopff. 1911. Price 6.50 Marks.)

This is the first part of what promises to be an extremely important work of reference, which will be found useful, not only to mineralogists, but also to chemists. It is to be completed in four volumes, each of 600-900 pages. The list of fifty-two contributors includes names of well-known workers in many countries, who are responsible for articles in branches of the subject with which they are specially acquainted. A work written on these lines is certain to be authoritative. The plan of the work is to give for groups and for species of minerals: analytical methods, tables of analyses, physico-chemical constants, methods of synthesis, modes of origin, alteration products met with in nature and prepared in the laboratory, and methods of treatment for technical uses. The subject is treated largely from the standpoint of physical chemistry. Very full references to the literature are given.

The present part includes a general introduction, and commences with carbon and the carbonates. Of the sixteen signed articles, mention may be made of: Analytical methods in general, and the analysis of carbonates, by M. Dittrich; Diamond, by C. Doelter; Graphite—chemical and physical characters, by W. Heinisch; Graphite—artificial production and technical applications, by R. Amberg; Chemical reactions of carbonates, by W. Meigen; Formation of calcium, magnesium, and iron carbonates, by G. Linck; Sodium carbonates, by R. Wegscheider.

We regret to have to draw attention to the large number of misprints; even in the list of contributors several of the names are printed incorrectly. One loses confidence in a work of reference so marred by careless editing. It is to be hoped that future parts will be improved in this respect.

Crystallography and Practical Crystal Measurement. By A. E. H. TUTTON.
Pp. xiv + 946, with 720 text-figures and 3 plates. (London :
Macmillan & Co. 1911. Price 30s. net.)

Almost all treatises of crystallography having hitherto been written by mineralogists, it is an advantage now to have the subject presented by one whose training has been that of a chemist. By bringing together these two different, and each no doubt somewhat limited, points of view, we gain a truer perspective of the common ground. The present volume treats, however, of chemical crystallography only to a limited extent, the underlying principles being those of the accurate measurement of crystals and their properties, and the elaboration of instruments for performing such measurements. It is, in fact, essentially a detailed record of the author's own methods, which he has worked out with infinite patience, and applied with signal success to the study of the isomorphous relations of certain groups of salts. This tendency is shown in the opening chapters on 'The preparation and selection of measurable crystals', 'The goniometer', and 'The measurement of crystal angles as exemplified on a crystal of potassium sulphate'. The subject-matter is divided into two parts—morphological and physical, and in all there are fifty-five chapters. We miss from these chapter-headings any mention of the electrical and magnetic properties of crystals, thermal conductivity, pseudo-symmetry and optical anomalies, polymorphism, morphotropy, homoeomorphism, &c.; nor are any of these subjects mentioned in the index. On the other hand, we find interesting chapters on 'Crystals as homogeneous structures' and 'Fedorov's theory of cubic and hypo-hexagonal types'.

To the worker in crystallography the book will be of great value in offering hints and suggestions as to methods of research, and the construction and use of instruments. The student would, however, we think, find some difficulty in discriminating between essential and unessential details, and would perhaps be discouraged by the mass of material presented. Certain special pieces of apparatus are described in the same minute detail as in the author's original memoirs in the *Philosophical Transactions*. In the examples of crystal calculations given for each system we find several similar zones each worked out in exactly the same way in the fullest possible detail. It seems almost unnecessary to devote two pages to the explanation of Napier's rules for the solution of right-angled spherical triangles; whilst to repeat the explanatory diagram no less than 63 times throughout the volume does not presume much intelligence on the part of the student.

Again, a diagram to illustrate the working of the anharmonic ratio is given 36 times. The illustrations (apart from the 99 just mentioned), and the printing and get-up of the volume leave nothing to be desired.

Leçons de Cristallographie. By G. FRIEDEL. Pp. iv + 310, with 383 text-figures. (Paris: A. Hermann & Fils. 1911. Price 10 francs.)

This excellent textbook on elementary crystallography is based on the author's lectures to engineering students of mineralogy at the National School of Mines of St. Etienne, of which school he is director. Starting with the idea of vectorial properties and the space-lattices of Bravais, the principles and more important details of geometrical crystallography (109 pp.) and of physical crystallography (98 pp.) are logically developed in such a manner as to be of educative value to the student. In the second part of the book the subject of complex crystalline structures (twins) and transformations is developed on the same lines. There are short chapters on isomorphism and polymorphism, and an appendix on Schoenflies's theory of crystal-structure. By reason of his experience in teaching and the amount of original work which he has done in several branches of crystallography, the author is well qualified to write a suggestive book of this kind. Unfortunately, the numerous text-figures are poorly, and often incorrectly, drawn, being rather of the nature of rough diagrams.

The Optical Properties of Crystals, with a general introduction to their Physical Properties. Being selected parts of the *Physical Crystallography* by P. GROTH. Translated from the fourth German edition by B. H. JACKSON. Pp. xiv + 309, with 121 text-figures and 2 coloured plates. (New York: John Wiley & Sons; London: Chapman & Hall. 1910. Price \$3.50 = 15s. net.)

Professor Groth's classical work, 'Physikalische Krystallographie,' which first appeared in 1876 and reached a fourth edition in 1905, should surely have been translated into English before now; for, until recently, there has been no good book in our language on the physical branches of crystallography. The present translation, however, covers only one-quarter of the original, being confined to the optical portion. Pages 1-252 of the translation correspond exactly with pages 1-176 of the fourth German edition, whilst the remaining 38 pages give an abridgement, with some rearrangement in the order, of the influence of other physical characters on the optical properties of crystals. The work of translation has been exceedingly well done by Mr. B. H. Jackson, of

the University of Colorado, at Boulder, Colorado. A few explanatory notes and references to recent work are added. In an appendix, giving the names and addresses of mineral dealers and instrument makers, those of American firms are included. The book is one that may be strongly recommended to students of crystal optics.

Rock Minerals: their Chemical and Physical Characters and their Determination in thin Sections. By JOSEPH P. IDDINGS. 2nd edit., pp. xiii + 617, with 500 text-figures and coloured plate. (New York: John Wiley & Sons; London: Chapman & Hall. 1911. Price \$5.00 = 21s. net.)

The first edition of Professor Iddings's excellent treatise on rock-forming minerals was published in 1906 (noticed in this Magazine, vol. xiv, p. 416), and the fact that it has so soon reached a second edition speaks well for its usefulness and popularity. It takes the place of the author's earlier translation and abridgement of Rosenbusch's 'Microscopical Physiography of Rock-making Minerals'. The only alterations made in the new edition are by way of additions, there being an increase of 69 pages. In the first portion, dealing with general principles, the new matter relates to pleochroic halos, and Michel Lévy's diagram of extinction angles in the plagioclases. In the descriptive portion, 82 additional species of minerals are described. These include benitoite, the new feldspars anemousite and carnegieite, and the new amphibole rhönite; the others (beryl, columbite, barytes, galena, diamond, &c.) are simply copied from Dana. The book otherwise remains exactly as before, even to the misprints.

Der Diamant. Eine Studie von A. VON FERSMANN und V. GOLDSCHMIDT. Pp. xvii + 274, with 206 text-figures and Atlas of 43 plates (292 figs.). (Heidelberg: C. Winter. 1911. Price 10 Marks.)

This is the most elaborate monograph on the crystallography of diamond that has yet appeared. But apart from this fact, the book will be of special interest to crystallographers in that it develops a hitherto neglected method of research. The light-figures reflected from the surfaces of crystals were long ago noticed by Sir David Brewster, and they are seen every day when crystals are measured on the goniometer, but very little advance has been made in their systematic study. The present authors have realized that crystals of diamond, with their striated, curved, and etched surfaces, form excellent material for this study. The majority of diamond crystals give no clear and sharp reflected image of

a spot of light, but only streaks, curved bands, stars, and patches. Such crystals cannot be satisfactorily examined by the ordinary methods of goniometric measurement; it becomes necessary to record the positions of the bands, &c., with the aid of a two-circle goniometer, and to plot these carefully on a projection. Of the 289 crystals which were so examined, detailed descriptions are given of 131; these are represented by beautifully executed shaded drawings and by coloured gnomonic projections. This has been done with a thoroughness that characterizes all Professor Goldschmidt's work. The list of forms of diamond, instead of being increased (with one exception, viz. the form 322), is reduced to the following eight typical forms, which are the only ones present as plane faces:

(100) (211) (322) (111) (332) (221) (331) (110).

Of still further general interest is the very clear and philosophical discussion of the growth and solution of diamond crystals as evidenced by their surface characters and the forms of the light-figures. Light-figures of one type are characteristic of processes of growth, and those of another type of processes of solution. Comparatively few crystals exhibit evidences of growth alone; some show that growth and solution have taken place simultaneously on different areas; whilst the majority show unmistakable signs of solution. In diamond, the octahedron is the face of maximum growth, and the cube that of maximum solution.

An historical chapter and a useful bibliography of 402 titles are given. The latter contains several misprints and rather unnecessary abbreviations: some of the English words as curtailed in titles look quite unfamiliar.

British and Foreign Building Stones. A descriptive catalogue of the specimens in the Sedgwick Museum, Cambridge. By JOHN WATSON. Pp. viii + 483. (Cambridge: University Press. 1911. Price 3s. net.)

The instructive collection of building stones brought together and installed in the Sedgwick Museum by Mr. Watson consists of 1,126 specimens, mostly in the form of $4\frac{1}{2}$ -inch cubes with one face polished. The particulars given in the catalogue for each example include: trade-name, petrographical name, colour and texture, name of quarry and its situation, name of donor, percentage chemical composition when known, specific gravity and weight per cubic foot, and crushing strain per square foot. There are 420 examples of British building stones, arranged in the following groups: igneous rocks (plutonic), igneous rocks (volcanic),

metamorphic rocks, and sedimentary rocks, the last in eight subdivisions according to geological age. The colonial and foreign building stones are also arranged on the same plan. A very full index of 53 pages facilitates reference to the catalogue. One-half of the volume is occupied by an introduction and 'descriptive notes'; this is especially interesting and readable, and gives a general account of the distribution and working of the stones of each group in different countries all over the globe. Mention is also made of buildings, with their dates of erection, in which the different kinds of stone have been employed.

The book is issued in a handy form and at a moderate price. It is full of facts and useful information, and will be found of value to many others besides the geological student for whom it is intended as a guide to the collection. We await with interest the companion volumes promised for the collections of 'Ornamental and decorative rocks', 'Stones suitable for paving and road making', and 'Roofing slates and flags'.

Tables for the Determination of Minerals, by means of their physical properties, occurrences, and associates. By E. H. KRAUS and W. F. HUNT. Pp. vii + 254. (New York and London: McGraw-Hill Book Co. 1911. Price \$2.00 = 8s. 6d. net.)

These tables give a somewhat elaborate key for the determination of 250 common minerals, and are based on the following easily determined characters: (i) lustre (metallic or non-metallic); (ii) colour (by which five groups are recognized); (iii) streak (two sub-groups); and hardness (H. = 1-3, 3-6, or over 6). In this way 41 pigeon-holes are provided for the 250 minerals, but as many of the species are repeated several times (some as many as eight times) there is in places considerable overcrowding; and this, in a rule-of-thumb method, would no doubt confuse the beginner. Other prominent characters (chemical composition, crystalline form, cleavage, specific gravity, &c.) are mentioned for each mineral, and of special interest are the statements of modes of occurrence and associated minerals; but no simple chemical tests by which the determinations could be confirmed are given.

Calcites of New York. By HERBERT P. WHITLOCK. 4to, pp. 1-190, with 27 plates. (Albany: New York State Museum, Memoir 13, 1910.)

This work supersedes the much-quoted monography of J. R. McIrby (1879) on the crystallography of calcite. The beautiful and well-known

crystals from the old lead mines near Rossie in St. Lawrence Co., as well as those from nineteen other localities in the State of New York, are described in detail. In addition is given a very full bibliography of 1196 titles on the crystallography of calcite in general, and a list of 313 crystal-forms, together with a supplementary list of 115 doubtful forms, observed on this mineral. The symbols of Naumann, Miller, Bravais-Miller, Lévy, and Mohs, and the first observer, date, and locality are given for each form. A gnomonic projection of the forms is given on a large sheet (measuring $3\frac{1}{2}$ feet across). Finally, there is a brief but interesting discussion on the influence of the genetic conditions on the habit of the crystals. Crystals bearing the steep hexagonal pyramid (8.8.16.3) appear to have been deposited from solutions rich in silica, whilst those with negative scalenohedra in the zone $[01\bar{1}2, 11\bar{2}0]$ occur in iron-ore deposits.

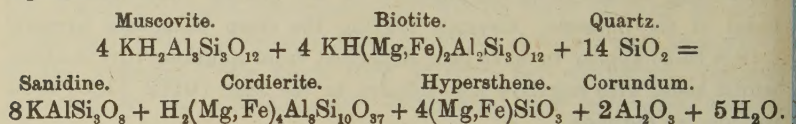
The Growth of a Crystal. By HENRY A. MIERS. Pp. 32. (London: H. Frowde. 1911. Price 1s. net.)

This pamphlet contains the substance of the eighteenth Robert Boyle Lecture delivered before the Oxford University Junior Scientific Club on May 20, 1911, a day which happened to be the fifteenth anniversary of the author's inaugural lecture as Waynflete Professor of Mineralogy in 1896. He therefore very appropriately gives, in an interesting and popular manner, a general summary of the results of the important work on the growth of crystals which was performed by him and his pupils during the thirteen years he remained in Oxford. Stress is laid on the importance of analogies in suggesting lines for future work, and several interesting ideas are presented; amongst others, that the particles of crystals should be regarded as being in rhythmical motion rather than as being rigidly fixed in position.

Die kristallinen Schiefer des Laacher Seegebietes und ihre Umbildung zu Sanidinit. By REINHARD BRAUNS. 4to portfolio, pp. 61, with 18 plates. (Stuttgart: E. Schweizerbart'sche Verlagsbuchhandlung, Nägele und Dr. Sproesser. 1911. Price 24 Marks.)

In a series of sixty-eight beautifully reproduced photomicrographs of thin rock-sections clear evidence is given of the complex mineral changes that have taken place in the blocks of schistose rocks ejected by the volcanoes of the Laacher See district. These schistose rocks (gneiss, mica-schist, and phyllites), themselves produced by the dynamo-

metamorphism of sedimentary rocks of Lower Devonian age, consist of quartz, muscovite, and biotite, with red garnet, staurolite, kyanite, sillimanite, &c. By the action of contact-metamorphism andalusite has been developed in them. But when the blocks have been caught up in the magma they have undergone a more profound alteration (pyro-metamorphism), their constituent minerals having been fused and re-constructed. The new generation of minerals so produced include spinel, corundum, magnetite, cordierite, sanidine, hypersthene, biotite, &c. That such changes are chemically possible is shown by the equation:



It is therefore concluded that the ejected blocks of sanidinite have been produced by the pyro-metamorphism of schistose rocks.
